Assistance systems in learning factories

A systematizing overview and case studies

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1. Introduction

In performing production tasks and processes, employees require both theoretical and practical knowledge (Lassen, McKelvey & Ljungberg, 2018). Especially in adaptive production systems called for in Industry 4.0, learning is not merely instructional but always has to encompass a degree of immersion to impart the complex interplay of task and technology (Schuster et al, 2016). For this reason, learning on- and near-the-job gain importance. In order not to interrupt real production processes and to avoid faulty production, simulated working environments in learning factories can be used for learning purposes. This paper discusses assistance systems that support learning in production processes. The goal of the paper is to structure the possibilities of assistance systems use regarding different learning goals.

Learning systems can be used at different stages within a production process. Accordingly, they are also deployed in various stages of the learning process (Wandke, 2005). With the specificity of learning of production technology and processes, assistance systems can provide awareness, information, direction, and feedback. Guiding the attention of the learner and providing information within a real-life scenario is seen as beneficial and instructive. Yet, learning objectives differ and assistance systems need to be selected and embedded in a learning scenario adequately.

To address this selection and integration problem, we first present a taxonomy for assistance systems that encompasses different stages in the production process (section 2). We furthermore extend this taxonomy with learning theories and objectives to classify assistance system use (section 3). The resulting extended taxonomy of assistant system use in learning factories describes single and integrated usage scenarios (section 4). A case-study approach (section 5) is used to demonstrate this taxonomy. Through three exemplary cases, different areas of the taxonomy are presented. The benefits and obstacles of each scenario are described (section 6).

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2. Taxonomy of assistance systems

Assistance systems are in use in different domains from their application in everyday life like driving cars and guiding the operation of information systems to industrial usage e.g., in operating machinery, maintaining facilities, and monitoring production processes. The main purpose of assistance systems is to extend the capabilities of human operators in different aspects to achieve an individual or organizational goal faster, with fewer errors, or more secure. Assistance systems thereby enhance perceptual (visual, tactile, hearing), decision-making (information-presentation, pre-processing), and activity (range extension, strength amplification) capabilities (Mark, Rauch & Matt, 2021).

2.1. Classification by interaction stage

To structure types of assistance systems, Wandke (2005) proposes a six-step taxonomy that is oriented towards a flow of activities that can be assisted. Starting from motivation and activation through perception, information integration, decision making, and activity execution to feedback, assistance systems can provide different extensions to human capabilities. Within each activity, there are different ways in which assistance systems are involved.

In the *motivation and activation* stage, assistance systems nudge humans to execute desired activities through activation, coaching, and orientation or omit undesired activities through warnings (Dostert & Müller, 2020). Typical systems can be found in wearables, which keep the user updated about their activity goals or which monitor health parameters.

At the *perception* stage, assistance systems display and present environmental information, they guide the attention of the user (Bottani & Vignali, 2019). Furthermore, they can be used to amplify or filter environmental signals to focus attention. They thereby extend the human ability to extract information from the environment. Examples are driving assistance systems and haptic feedback systems.

While systems in the perception stage interface between the user and the environment, the next stage enriches input signals with *additional information* and contextualizes the inputs (Alm & Hadlak, 2015). Typical applications label signals from the environment, interpret situations, or even explain the environment or usage context to the user. Examples for these applications can be found in augmented reality supplements, where status data about machinery is displayed for the worker.

Systems in the fourth stage go beyond informing and recontextualizing situations. Active decision support or even autonomous *decision-making* characterizes these systems (Nelles, et al, 2016). They either supply, filter, or propose decisions. At this stage, humans select the final decisions, yet the scope of these systems already goes beyond this capability.

Active decision-making by delegation, take-over, or even silent execution can be found here. The decision-making capabilities of assistance systems are found in autonomous factory settings or in risk-prone operating environments, where erroneous and dangerous human decisions are blocked or questioned by the system.

Besides decision-making, assistance systems are involved in the *action execution*. While human muscular power and coordination are limited, systems can amplify power e.g., through exoskeletons or limit and dose human power in sensitive areas. Assistance systems in this area are closely associated with human movements and need to capture and translate (Mark, Rauch & Matt, 2021).

The sixth stage of the taxonomy is related to the *feedback* assistance systems can provide, when actions are executed. This can be a simple report about the state in which the technology is, but it can also encompass a critical retrospective of human actions (Yang & Plewe, 2016).

2.2. Classification by interaction type

Aside from the different stages of human support, assistance systems can *interact* with their context differently (Wandke, 2005). Fixed assistance systems are not context-aware and just guide the operator in a predefined way. Customizable assistance systems allow are adjusted during design for the specific needs of the user group. Adaptable systems can be adjusted by the users to their specific need through parameterization. The assistance system is thereby interactive towards the user. In comparison, adaptive systems modify themselves regarding their environment and user behavior. They thereby need the capabilities to reason about their perceptions and actions. Adaptive systems often go along with AI capabilities. If the usage environment is uncertain and less predictable, a higher degree of adaptiveness is needed, while an anticipatable environment with little degrees of freedom allows fixed assistance systems.

The degree of interaction with the environment is also closely related to the type of *initiative* an assistance system provides (Wandke, 2005). Passive systems need to be triggered by the human to provide help. Active systems are engaging the user by perceiving the assistance situation themselves. In all presented stages, passive and active systems can be used. However, in warning, orientation, and activation systems they need to be active, as they are the guiding factor in the interaction between user and environment.

2.3. Classification by presentation type

The third way of classification is the type, in which the support is presented. Different media like texts, graphics, pictures, animations, videos, and sounds can be used to provide visual and audible assistance. Recently the augmentation of media and environment has become increasingly attractive. In general, the following *presentation modes* can be distinguished. *Mono-medial presentations* focus only on one output media e.g., by only presenting textual outputs as hints. *Multi-media presentations* on the other hand combine more than one output media. Especially when warning or hinting is required, a combination of visual, audible, and tactile channels can interrupt the user with more certainty. The third way of presenting the assistance is *implicit*. This mode of presentation is found when the assistance system is directing acting in the environment or is amplifying the actions of the user. Instead of receiving explicit hints, the user only experiences the effects of the assistance system e.g., if machinery is stopped due to faulty operation.

In the factory environment, assistance systems are often used in combination. As head-mounted displays guide workers through their tasks, machine interfaces provide feedback about the actions and direct the attention of the worker. Robotics or exoskeletons provide additional power. Often, multiple systems are coupled e.g., when the worker is interacting with a robot wearing a head-mounted display, which provides information about the robot's current tasks.

It is without saying, that assistance systems are ubiquitous in modern factories. However, it is unclear which impact these systems have on learning activities in a manufacturing setting. Taking the perspective from different learning theories and applying those to learning factories, guides the analysis.

3. Learning Theories and Learning Factories

The increasing velocity of changes in a factory setting requires constant adaption of the workers towards new technology. While traditional learning arrangements such as seminars, training-on-the-job, or workshops address the conveyance of factual knowledge, interactive concepts such as learning factories help to build up action knowledge.

3.1. Learning Factories

Learning factories enable workplace-oriented learning in technology-oriented learning environments in which production processes of real companies are simulated in detail but in an abstract manner (Gronau, Ullrich, & Teichmann, 2017).
Extensions with Industry 4.0 elements such as mobile Internet of Thing technologies (IoT technologies) demonstrate their impact and train their use in an individual context. The proximity to real processes and the resulting possibility of immediate contextualization of new knowledge content reduces the risk of any (knowledge) transfer problems. Theoretical knowledge and its practical application are linked by overcoming the difference between theory and practice. Learners from the manufacturing industry can thus independently develop competencies close to their own work process without being subject to the restrictions and constraints of the original system.

Although there is no exact definition of the term "learning factory", the use of model systems is a general characteristic feature (Grodotzki, Ortelt, & Tekkaya, 2018; Wagner, Al Geddawy, El Maraghy, & Müller, 2012). More specifically it contains two distinct aspects: the technical representation of an original factory system (model factory) and a didactic concept (learning context).

As a *model factory*, learning factories are thus technical model systems exist that represent original systems (e.g., production lines) and production processes. The elements of a model factory are combined into manufacturing sequences that represent the work process with simplified instances of the individual operations a model of the real product. In the form of workstations, actors (e.g., workers) can interact with the plant in different ways within processes and scenarios. The underlying model factory comprehensibly forms a terminating feature of the performance of a learning factory.

Various forms of interaction between process actors (human to human, human to machine, machine to machine) can be realized. The model character eliminates the risk and safety to humans or machinery in the original plant. Regarding the objective of training and learning, the general requirement of reproduction of the original is joined in particular by the requirement to allow learners to act in and explore a realistic environment. Learning factories, therefore, need to offer a sufficiently high level of immersion. Assistance systems can provide additional immersion in two aspects: as part of the represented real factory system (assistance system as an object of learning) or as a device that guides the learning process (assistance systems as a means of learning). In this paper, we consider the latter. Likewise, the usage of assistance systems needs to be assessed in the context of learning theories.

The second characterizing aspect of a learning factory is systematic knowledge transfer. This requires the use of a basic didactic fundament on which the implementation and application of the model factory rests. Hence, a model factory requires a suitable *didactic concept* to be able to act efficiently as a learning factory. The didactic concept is based on a selected learning theory. Regarding the learning objective, it defines the core didactic elements and levels from which the design of the learning scenarios is deduced.

3.2. Learning Theories

Several factors influence how adults learn, e.g., their life-centered, task-centered, or problem-centered, experiential, discovery-based orientation to learning (Kaufman, 2003; Knowles, 1970; Moon, 2013; Spencer & Jordan, 1999). Learning theories represent different assumptions about the processes of knowledge transfer that can be put into action, when planning learning scenarios and developing learning modules (Gardner & Thielen, 2015, p. 43). We will give an overview of the most widely used: behaviorism, cognitivism, constructivism, experiential learning, connetivism as well as multi-model learning.

Behaviorism (Skinner, 1965) sees knowledge as an external object that is not bound to the learner. Knowledge is conceptualized as showing the desired behavior, even without understanding the context (Gredler, 2005). Learning is conceptualized according to the stimulus-response scheme; thus, it aims at the repetition and routinization of learning material and tasks to initiate behavioral change. Typical learning modules are question-answer sequences (e.g., vocabulary training) and repetition of simple factual knowledge. No problem-solving skills and individual learning paths are not supported.

Cognitivism (Piaget, 1954) is a group of learning theories that relates learning to the cognitive operations of the learner. Knowledge is an object, which is transferred through the learner's internal cognitive processes. Learning is therefore seen as an individual information processing within the learning environment. The individual cognitive scheme can either be adapted to the environment (accommodation) or the environment can be changed through individual actions (assimilation). These approaches aim at exploratory learning to transfer processual knowledge (Erpenbeck & Sauter, 2013, p. 38).

Constructivism (Piaget, 1954) is one group of theories that are concerned with learning through exploration and experimentation. Learning is seen as the ability to identify and solve problems independently. Knowledge is therefore not transferred but constructed internally by the individual. New knowledge is linked with existing knowledge (Gardner & Thielen, 2015, pp. 54-55). The construction process relies on active interaction with the environment to establish cause-effect-relations. The construction process is furthermore a social process, in which the interaction with the teacher and other learners is constituting the learning results. The process of construction can again be guided by individual and situation-dependent learning paths (Erpenbeck & Sauter, 2013, p. 39). In contrast to behaviorism, constructivists stress that learning is a fuzzy process, which can in part be guided but is foremost dependent on the learner's ability to explore and experiment. Learning factories with their representation of the real factory are ideal to apply constructivist approaches as learning should take place at the workplace or in the environment where the knowledge is applied. Learners can communicate, collaborate, and experiment in a close to real scenario and environment. Learning success depends on the most realistic possible design of conditions and tasks in the laboratory. Also, guidance in exploring is provided through different learning paths. Intelligent tutorial systems are used to continuously diagnosing the learning process and instruct the learner accordingly.

One specific constructivist theory is the *experiential learning theory* (D. A. Kolb, 1984). Learning is thereby a process of knowledge creation through experience. Experiential Learning Theory aims at providing "a holistic model of a learning process and a multilinear model of adult development" (D. A. Kolb, Boyatzis, & Mainemelis, 2001). In the context of changing technologies and automation, these learning settings have been recognized by many companies as suitable for the acquisition of corresponding competencies (Kluge, 2007). According to (A. Y. Kolb

& Kolb, 2005), experimental learning is built on the following main propositions: Learning should be seen as a holistic process of adaptation to the world and results from synergetic transactions between the person and the environment. It is best conceived not in terms of outcomes but much more a process of creating knowledge. The main advantages of experiential learning are associated with the high learner activity and with the possibility to create an appropriate learning environment especially for vocational trainees (Kluge, 2007). Kolb (1984) defines four stages of learning are proposed, into which different activities can be subsumed:

- The concrete experience of a person carrying out a particular action;
- observation and reflection of the effect of the action in a particular situation;
- formation of abstract concepts and understanding the general principle under which the particular instance falls;
- testing of the concepts in new situations.

This learning theory is closely related to the ideas represented in learning factories. The model factory aspect eases experimentation and testing of assumptions without risking safety or disrupting operations. This is especially true when learners are confronted with new technologies. Didactical means as instructional material, well-designed tasks, and scenarios, as well as personal and digital interaction, can help in reflection and abstraction. Assistance systems can be used to enrich the experience, guide through the scenario, and present instructional material.

Connectivism (Siemens, 2005) focuses on interaction. Knowledge is seen as socially enacted and present in networks between learners, information, and its environment. Learning is thus not knowing how to solve problems but locating persons or entities who can and reflecting their ability to do so (Erpenbeck & Sauter, 2013, pp. 41-42). It is thereby not factual knowledge, which is focused upon, but capabilities of actors and entities. Especially in networked factories, where personal is highly trained and specialized and smart devices possess knowledge and decision-making capabilities, one needs to identify the relevant knowledge carrier with the capability to solve a problem. In this view, learning factories should provide means to network within and across groups of learners. The learning factory setting can ease initial interaction through collaborative scenarios, which are not typical in a real factory environment.

Learning factories can incorporate multiple theoretical approaches in the development of learning scenarios. The selection of the appropriate theory used to design tasks, instructions, and feedback is guided by the objectives of the scenario. Bloom's *taxonomy of educational objectives* (Bloom, 1956) helps to structure learning activities and materials. It is a hierarchy containing six stages: remembering, comprehend, applying, analyzing, evaluating, and creating. A refinement of this taxonomy expands the six stages with concrete activities and connects the activities to the acquisition of factual, conceptual, procedural, or metacognitive knowledge (Airasian, 2001). A learning scenario should encompass objectives from different stages in ascending order. Learners are confronted with more behavioral (remembering), later with cognitivist (comprehend) and constructivist (applying, analyzing, evaluating) and connectivist (creating) aspects. Assistance systems in learning factories should be used with the educational objectives in mind. Using assistance systems, which only present instructions without being context-aware, could lead to frustration with the learner as they have progressed beyond the stage of remembering and want to actively engage in exploration.

3.3. Multi-modal learning as the preferred learning approach

The didactic concept is understood as a practice-oriented guide to pedagogical work based on subject-oriented learning theory. It guides the use of digital media in the learning scenario. Different media can be used to present the necessary information. Since different cognitive styles prevail in the learner population, there is no one-media-fits-all approach. Some learners might respond better to textual presentation, while others prefer auditive or video explanations. A multi-modal learning approach is therefore preferred.

In essence, multimodal learning environments are such, where students are presented with a verbal as well as a corresponding visual representation of the content (Moreno & Mayer, 2007, p. 310). Another prominent aspect of those more complex learning environments, compared to a classical lecture format or the mere reading of content, is the interactiveness of the environment, where learning depends on the actions of the learner. Moreno (2006) explains this enhanced learning effect with the complex cognitive-affective theory of learning with media, which is based on human cognitive modes of action, its constraints, as well as affective, and motivational components. Its core message about how learning can be fostered is to create a most interactive, realistic, individually motivational, and content-focused learning environment. Basically, study material should be presented in such a way, that several senses are activated and thus the information gets more thoroughly mentally represented. However, using diverse multimedia in itself is not sufficient, what also matters is that diverse modalities, like auditorial, visual and tactile, are addressed, since the sensory memory is limited to one input at a time, respectively (Baddeley, 1992). This means that information in a learning setting can easily be neglected simply due to an overload within a sensory channel (Moreno & Mayer, 2002). Further, learning is increased when the learning material is presented in a coherent, integrated fashion as it would be in real life. For example, when viewing a video where a person demonstrates a certain technique, further explanations should naturally come along with the visual material and not separately after the video, preferably auditorial and not in text form. What might seem trivial is often enough not the case in formal learning settings (Birdwell, Scott, & Koninckx, 2015).

On top of the mere cognitive-stimulating aspect of multimodal learning, these kinds of learning environments include another most prominent facilitating aspect concerning learning. Their interactivity, as well as the possibility to personalize the learning experience can increase the understanding as well as the motivation for the learner to engage with the content. Chen (2008) could show this beneficial effect of personalized learning in the case of e-learning material. In the study, for half of the participants, the learning content could be adapted to the competence and speed of the learner, whereas the other part was confronted with standard e-learning platforms. The adaptation group showed superior learning outcomes compared to those standardized learners. Especially with the technology used in those learning settings, a direct and prompt adaptation according to the learner's individual needs is possible.

The variety of assistance system classes presented in section 2.1 allows a mix of different presentation and feedback options. Multi-modal learning can thus be supported by assistance systems on different levels: content can be presented, learners can be instructed, interaction can be initiated and feedback about the environment augmented. Also, personalization is possible if adaptive assistance systems are used in learning.

Assistance systems, therefore, provide different facetted cognitive representations and augment learning within the learning factory environment. Through immersion and stronger association of the learned content with real situations, learning success, self-efficiency and confidence can be increased.

4. Usage of assistance systems in Learning factories

The potential of assistance systems in learning factories can be assessed by combining the application purpose and the learning objective. The application purpose is derived from the aforementioned taxonomy by Wandke (2005). The stages of assistance system use address the model factory characteristic of a learning factory. The general notion of this taxonomy needs to be specified regarding the didactic concept to match the requirements for learning factories. In each stage, different learning objectives can be pursued regarding learning theories. Using Bloom's revised taxonomy (Airasian, 2001) adds learning objectives to the assessment. A conceptual 6x6 matrix results (see Table 1). Each cell represents a use-case of assistance systems as means to present and explore learning content.

		Stage of Activity					
		Activation	Perception	Infor-mation	Decision Making	Action Execution	Feedback
Learning Objec- .	Remember						
	Comprehend						
	Apply						
	Analyze						
	Evaluate						
	Create						

Table 1: Combined Taxonomy of Assistance Systems in Learning Factories

When planning and executing learning scenarios, use-cases are not regarded in isolation but bundled. Thus, learning scenarios capture multiple fields of the matrix. Depending on the purpose of the scenario, different patterns can emerge in this matrix. A process-oriented scenario can address the comprehension objective in all activity stages (horizontal path), in-depth learning on the other hand can vertically transverse the matrix e.g., to learn, apply and analyze production processes through perceptive assistance systems. Other combinations to design learning scenarios with multiple assistance systems for different tasks are also possible e.g. when moving through the matrix diagonally.

The matrix can be used to assess the applicability of assistance systems by different means. First, conceptualizing the assistance system use for a specific objective can be harder in different stages e.g., when combining comprehension with action execution, two conceptually different aspects: the cognitive requirements of comprehension need to be bridged with the haptic requirements of action execution. Secondly, the implementation of the assistance system requires different efforts in each stage-objective combination. This is due to different degrees of interactivity and adaptability; thus, certain combinations can be hard to implement and should be better achieved with different presentation means. Thirdly, the implemented scenario needs to be accepted by the user respectively the learner. This allows a differentiated assessment of assistance systems for learning purposes like age, educational background, or existing production and technology experience can impact the acceptance of certain assistance systems.

The developed taxonomy is partially tested using a case study approach. Cases highlight different paths, objectives, benefits, and obstacles in implementing assistance systems in learning factories.

5. Research Design

To demonstrate the taxonomy and the areas of application of assistance systems in learning factories, a case-study design was chosen. A case study approach is applicable if a real-world phenomenon should be explored and an experimental setting cannot be applied (Yin, 2009). A "case study is an in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular project, policy, institution, program or system in a "real-life" context." (Simons, 2009, p. 21)

Since the application of assistance systems in a learning factory involves technical, cognitive, and social aspects a systematic quantitative study is only possible for distinct, well-defined problems. Due to the multiple perspectives, the possibilities and effects assumed in our taxonomy need to be investigated exploratively.

Case studies offer a structured way to describe, interpret and evaluate a real-life phenomenon (Merriam, 1988; Stake, 1995). Different perspectives can be taken, regarding case study research (Ridder, 2017). In our case, the application of theoretical aspects (learning theory) in combination with assistance systems is applied (Bassey, 1999). Since this is not done exhaustively, the cases are illustrative using storytelling rather than evaluative or interpretive. Furthermore, the cases were derived from scenarios that were implemented independently from the existing taxonomy. The three scenarios were designed with multiple specific educational objectives and purposes in mind.

To situate the case studies, a differentiation according to subject, purpose, approach, and process of case study is proposed (Thomas, 2011).

- *Subject:* We present three cases from our experience in implementing and operating a learning factory. Each case represents a different assistance system and a different educational purpose according to the taxonomy presented above.
- *Purpose:* Each case should be used to evaluate the capabilities of assistance systems in learning factories for the specified objectives.
- *Approach:* We chose a descriptive and interpretative approach,
- *Process:* we conducted multiple case studies spanning different areas of application of assistance systems. The studies were conducted sequentially and described in retrospect.

The case studies were conducted in the learning factory which is part of the *Center Industry 4.0 in Potsdam (CIP4.0)*. Its simulation environment uses a hybrid approach for factory modeling. This approach combines a physical model factory with computer-aided simulation. From a didactic perspective, CIP4.0 uses clearly defined didactic levels (macro, meso, and micro levels). While questions about participation in continuing education are located at the macro level, the meso level deals with the planning and implementation of continuing education projects. On the micro-level, on the other hand, the micro-didactic design of concrete teaching and learning situations in learning scenarios is addressed. Concretely there are learning modules, which combine elements of the model factory, and competence modules to sub-scenarios which are orchestrated to form a learning scenario. This provides a flexible setup of learning situations and allows the actors a high degree of freedom of interacting in the typical factory environment. The participative, human-centered approach indented the inclusion of the individual action problems or (learning) interests of the participants throughout the entire continuing education process (Teichmann, Lass, Ullrich, & Gronau, 2021).

Data about the three cases were collected during the conceptualization, implementation, and execution of three different learning scenarios. Each had distinct objectives, which can be associated with the categories derived from the learning theories. Meeting minutes and interviews were used to gather data in the conceptualization and implementation phase. Observation, log data analysis, and user surveys provided data to assess the execution of each scenario.

6. Cases of Assistance systems in Learning Factories

The cases span different purposes and formats. The first case captures the use of assistance systems to explore different technological aspects and foster group interaction. The second case focuses on the purely instructive side of assistance systems to guide activities and provide process information. In the third case assistance systems address two aspects: they are part of the simulated factory setting as devices used in production and they are means to guide the users' attention through the scenario. The following sections classify, describe, and assess each case.

6.1. Technology exploration

The first case study presents training on the topics of digitalization as a social phenomenon, safety, and security, risks and challenges, opportunities. The one-day workshops were conducted with worker union representatives of different manufacturing enterprises (Teichmann, Ullrich, Wenz, & Gronau, 2020). This learning environment addresses the topic of organizational change (Abele, Metternich, & Tisch, 2019), whereby the main goal is to prepare key decision-makers for concrete and abstract challenges caused by digitalization processes in society and in their organization. Assistance systems were used to guide the users and provide additional material about the technology.

Case 1: *Technology Exploration*	
Learning objective	Development of general understanding regarding digitalization, technology, and organizational change
Learning approach	Experiential Learning, Connectivism, Constructivism
Stage	Motivation, Awareness, Perception, Decision Making
Assistance Systems	AR glasses, tablets, simulator
Scenario description	The training on technology use is characterized by simulated production processes, different work tasks, and situations as well as by the continuous integration of relevant Industrial Internet of Things (IIoT) technologies (e.g., augmented reality (AR) glasses, AutoID technologies, CPS as well as intelligent workpieces and machines). The learners are confronted with a changeover between product variants during the current production process and the associated production process modifications. With the help of AR glasses and tablets, they must calibrate the machines, powder coating, and quality control that have now to be used according to the product specifications and integrate them into the production process. Certain process modifications initiate further changes as a result, whereby the task portfolio is constantly expanded and supplemented by new challenges regarding one's own process competence. The participants communicate with each other and develop collaborative work processes to prevent the imminent stop of the production process. The thematic workshop includes presentations and lectures on different digitalization-related topics and aims to develop the acceptance of the idea and reduce fears and uncertainties.
Benefits	Learners are continuously encouraged to apply relevant IIoT competencies in realistic learning environments and, building on these, to develop their own options for action in critical production situations. The learning concept furthermore includes presentations and lectures on different digitalization-related topics and aims to develop the acceptance of the idea and reduce fears and uncertainties. The acceptance of organizational changes by employees and decision-makers is increased by the fact that they develop a generally better understanding of the changes caused by digitization.
Obstacles	The acceptance of assistance systems in this learning process is age and experience-dependent. Some participants had difficulties, engaging with the new teaching technology. The additional

	workshops were introduced as a reaction. Furthermore, the contents were not customizable, the participant's level of knowledge should be assessed in advance. Participants who have already gained extensive experience with digital technologies may be under-challenged, whereas beginners in the topic may be over-challenged. The sustainability of the knowledge imparted is questionable if the participants cannot subsequently apply their new competencies in their own practice.

Table 2: Technology Exploration

6.2. Tablet-based initial learning

The second case presents the initial learning of manufacturing processes in a simulated environment. This learning environment addresses the production process topic of learning factories (Abele et al., 2019) and has been developed on the example of the production process of artificial knee joints. Two learning scenarios will be presented to describe the advantages of the learning factory. Both were conducted in the context of the simulated production process, but with different experimental settings and objectives. An assistance system (tablet-based) was used to introduce the participants to the process and provide hints during the process execution.

Case 2: Task and process learning	
Learning objective	Development of concrete digital competencies to perform tasks in the context of a concrete industrial process
Learning approach	Behavioristic, Constructivist
Stage	Information, Decision Making
Assistance Systems	Tablet with walkthrough, simulator
Scenario description	Using original noise, pictures, and videos from actual machines, real-world processes of knee-implant production are mimicked as closely as possible. The participants engage with machines with touch surfaces and manipulate workpieces (which are computers with three screens in form of boxes that move on top of the transportation systems). Further, participants use other technical services like scanners and robots, dependent on which part of the manufacturing process they are working on. The focus lies on the use of digital assistant systems in the training phase for a new production process (Vladova, Wotschack, de Paiva Lareiro, Gronau, & Thim, 2020). The necessary tasks of the workers were depicted in the AS (in the form of a tablet), which was specially developed for the experiment, and enriched with

	learning instructions. The test persons had the opportunity to either act independently for each learning step currently displayed in the AS or to press a "help button" at any time to obtain additional information and tips. The participants were divided into two groups and accordingly assigned to two different settings. In the first setting, the participants were given the AS as the only means of orientation and assistance right at the beginning and were taught the production steps exclusively in this way. In the second setting, on the other hand, the test persons received an additional ten-minute introduction by the experiment supervisor at the beginning of the experiment.
Benefits	The use of the assistance system allows completely inexperienced users to start directly in a production process. The aim is to repeat steps and thus internalize them, neglecting other interrelationships in the process. For example, temporary workers or employees who are assigned to certain tasks at short notice - e.g., as a result of job rotation - can benefit from being guided through the production steps that are relevant to them. They are also given the opportunity to specifically request help at each step as well as to go back one or more steps if necessary. The assistance is first provided by the assistance system and - in case it is not sufficient - also by the human trainer. Through the additional introduction to the process itself, which the control group receives in the experiment, constructivist learning methods can also be used. The social exchange is guaranteed here at the beginning and comprehensive knowledge and understanding of the process can be conveyed.
Obstacles	Common to both groups was the challenge of not getting direct feedback on whether the process step was completed correctly. Furthermore, participants in both groups - regardless of whether they found the assist system helpful - missed the social exchange. The teaching of process knowledge at the beginning was also a challenge for the work with the assistance system because this additional introduction affected the purely behavioristic learning approach.

Table 3: Task and Process Learning

6.3. AR guided production

The third case is presenting the supplementing of operational assistance systems with learning promoting components. Part of the concept of the is therefore the integration of learning promoting functions in the provided assistance system, so that work-accompanying learning can be realized in a targeted manner, and thus learning assistance and processing assistance merge. A systematic knowledge transfer is created by information access on different levels, which are predefined according to the learning situation, following the didactic concept, or are available to the learner for free decision. The central instrument of information access is the data glasses, which offer individual access and feedback according to context, learner, and situation.

Case 3: Data glasses for knowledge transfer	
Learning objective	The goal of the scenario is to increase the user competence of the actors to use confidently in the strongly technology-driven world of work, in particular, problem-solving competence through the targeted use of the tools of modern and future production systems using the example of AR-based information access.
Learning approach	Experiential Learning, Connectivism
Stage	Perception, Decision Making, Feedback
Assistance Systems	AR Glasses
Scenario description	The scenario uses a model of the optical lenses' production using I4.0 modules. The process includes several workstations (machines and manual workstations). The actors involved are the workers, foremen, and apprentices. They use mobile assistance systems of system-integrated tablets and data glasses to perform their tasks and thus ensure that production runs correctly. This includes monitoring the equipment with checks on numerous parameters during regular operation as well as dealing with malfunctions (repairs) and organizational turbulence (e.g., rush orders or external reprioritization of orders). For complex workflows, data glasses are used because they offer hands-free execution of work tasks as well as fast and effortless documentation of the situation, making work easier compared with tablets. In operationalization, the necessary work of the worker or foreman is mapped in the assistant system according to the role and individual information needs. This includes suggestions, recommendations, evaluated alternatives, release activities, dedicated checklists, and delegation mechanisms. Possible information accesses are detail views, online documentation, knowledgebase incl. best practices and involvement of a remote expert via remote session. Additional workflows are available for the trainee role, which particularly address the transfer of knowledge by extended feedback (e.g., by the foreman) even in the production process.

Benefits	The data glasses provide the actions of the respective task as a checklist. Reflecting on the current situation, the actor executes the work steps and makes decisions. This forms processing assistance. In addition, the actor is allowed to obtain further information. Likewise, the actor can check the results of his decisions, partly as a forecast, partly as an actual result. The pre- and post-data views provide not only a data-based decision and a reflection of results but also the abstraction of solution principles or the recognition of patterns, which can be reused in similar situations, if necessary, in an adapted form. This systematic knowledge transfer promotes the learning process according to Kolb's learning stages and complements the worker's guidance to a learning assistance system.
Obstacles	Challenges and obstacles identified in the course of numerous simulation runs during training courses and workshops are the accustoming of handling of the new medium of data glasses incl. voice recognition at the beginning and the initially different degree of acceptance of the assistance, as well as initial skepticism about the suggestions of the assistance system, using it fully as a tool and supplementing or changing the usual procedure. Furthermore, privacy concerns regarding employee transparency and fears of skill obsolescence and resulting substitutability of the employee delay immediate full application. Finally, the partial additional effort in authoring regarding the preparation and linking of potential information should be mentioned.

Table 4: Data glasses for knowledge transfer

7. Conclusion and further research

Assistance systems can play an important role in designing scenarios in learning factories. Yet, the need to be selected and implemented carefully. This paper presented a taxonomy, which allows classifying different usage aspects regarding the activity stage and the learning objectives. By combining both dimensions, aspects of the model factory (stage-based) and the learning activity (objective-based) are considered. By demonstrating different paths through the taxonomy, appropriate learning scenarios can be developed, and their applicability can be assessed accordingly. We demonstrated the use of the taxonomy in three cases, where different objectives were met with specific assistance systems. In each case, the benefits, and obstacles, which were assessed point to improvement potentials of each scenario. However, the test of the taxonomy is limited in scope. Future work needs to test more fields and systematically assess different scenarios in the taxonomy to discover combinations and paths which are hard to conceptualize and implement. Furthermore, the cases did not provide insights into the learning success of the participants. Outcomes from the use of assistance systems should be systematically compared between assistance systems and with traditional learning devices.

The presented approach is a starting point for the systematic development and integration of assistance systems in learning factories.

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