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Towards a Classification of Learning Support Systems at the Digitized Workplace

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Abstract: In light of the transformation to cyber-physical production systems in Industry 4.0, the increasing trend of digitalization and product customization together with the demographic changes in Germany reveal a clear need for supporting the employees' sustainable competences development at the workplace. In this context, technology-enhanced learning environments provide new approaches for developing the vocational training system at the workplace. This paper discusses the pedagogical, didactic and technical aspects that characterize learning systems at the manufacturing and digitized workplace. Furthermore, a set of current learning solutions for supporting the employees' informal learning under industrial settings will be classified based on the introduced scheme as a foundation for a more comprehensive overview in future.

Keywords: Workplace Learning; Assistance System; Learning Platform; Industry 4.0.

1 Motivation

The increasing digitization of manufacturing enabled by cyber-physical systems (CPS) and of other processes in the supply chain will enforce changes in terms of qualification requirements, the quality of work, the organization forms of work and cooperation between humans and technology [Bo15]. The assembly industry will need innovative learning solutions to provide the workers with the required competences for assembling, picking and setting-up the products through short and fast learning activities. Furthermore, the move towards digitalization in the context of industry 4.0 will cause steady increase in the complexity of production process control as well as the operation and maintenance of the equipments [HK14]. Accordingly, the employees' tasks will primary involve activities of monitoring highly automated processes and regular intervention to keep the process under normal operating conditions.

Recently, many research projects have addressed the major challenges for updating the vocational training system in order to meet the growing need for sustainable competences development. However, to the best of our knowledge, there is no comprehensive scheme to classify the various workplace learning solutions, which can be essential to identify areas that are currently disregarded or deemed challenging for research. In this work, we propose a first classification scheme which explains and relates the different concepts and terms that characterize learning solutions for the digitized workplace.

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2 Classification Criteria

The proposed criteria for classifying the workplace learning systems, in accordance with the technological, didactic and pedagogical perspectives, were selected based on an intensive study of related work and analysis of twenty two concrete workplace learning systems.

2.1 Job Type

Due to the variety of activities at the workplace, it is basically useful to align the analysis to the nature of each activity. One potential approach is to classify activities according to their task diversity (the number of different tasks) and the presence or absence of analyzability (the possibility of dismantling the task into standardized steps) [LM07].

- *Routine Work*: Routine work follows a mechanical structure where a low level of task diversity and a high level of standardized task steps can be recognized.
- *Engineering (technical skilled workers)*: In engineering the task diversity is higher than in routine work but the analyzability is still moderate or high.
- *Crafted Work (craft industry)*: It is characterized by low task diversity and moderate standardization of the task steps.
- *Non-Routine Work*: Non-routine work represents the other extreme side of activity nature with high task diversity and low standardization of task steps.

2.2 Workplace Learning

Eraut et al. [Er10] proposed a scheme for classifying different modes of work-related learning. We complemented Eraut's definition of modes with new examples.

- *Work Processes with Learning as a By-Product*: Learning occurs spontaneously and unintentional through knowledge acquisition during the work process, e.g. trying things out or working alongside others and observing them.
- *Learning Processes at or near the Workplace*: Learning schemes in or near the workplace include processes whose primary object is learning. Supervision, coaching and mentoring are at or near the learner's normal workplace. Self-directed learning towards a new qualification based on learning resources like online trainings or microlearning contents and learning in collaborative learning scenarios with colleagues, like synchronous online classrooms, are other examples.
- *Learning Activities Integrated within the Processes*: Learning activities can be found in short opportunistic episodes during the work, also they are embedded within most of the working and learning processes. These activities include asking questions and getting information as a proactive activities. Additionally, listening and observing activities can help in learning tacit knowledge. Other activities include learning from mistakes, reflection and giving and receiving feedback.

2.3 Instructional Strategies

Cognitive apprenticeship is a social learning theory in which a master of a skill tries to help apprentice to become an expert through legitimate peripheral participation. It has been shown to be valuable in vocational training where a learner should be accompanied by an expert [JT94]. Collins et al. proposed six instructional strategies [CBH91].

- *Modeling*: In modeling an expert demonstrates a task explicitly by explaining how and why to perform different activities for task completion.
- *Coaching*: Coaching involves observing the learner task performance and providing feedback and hints to improve his performance.
- *Scaffolding*: Scaffolding is the act of putting into place strategies and methods to adjust the task complexity to match the learner performance level and to guide the learner through the task.
- *Articulation*: Articulation is the process by which the learner tries to articulate to other learners his knowledge, reasoning, or problem-solving process.
- *Reflection*: In reflection the learner looks back and analyzes his process and compare it with those of the expert to highlight the differences and similarities.
- *Exploration*: Exploration involves pushing the learner to frame his own interesting problems and questions and then take the initiative to solve these problems.

2.4 Learning Methods

Different forms of technology-enhanced learning, relevant in vocational training, can be distinguished.

- *Distance and Web-based Training and Blended Learning*: Distance and web-based training combine the provision of learning resources in different formats i.e. audio/video, text and animation with communication functionality i.e. in forums, blogs or online conferences. Blended learning is a hybrid methodology where portion of the traditional classroom learning activities are replaced by distance and web-based training forms.
- *Social and Collaborative Learning*: Social learning is characterized by participation and collaboration. The knowledge in social learning is collaboratively developed and processed. In this form of learning, social media and community platforms or specialized computer-supported collaborative learning (CSCL) tools are used in order to develop new knowledge in exchange with other members [Di99].
- *Mobile and Ubiquitous Learning*: Mobile learning mainly focuses on the mobility of the learner and describes the support of learning processes by using mobile devices. It allows the learners ubiquitous ”just-in-time” delivery of knowledge and information in the actual context [SE13] independent from the location.

- *Microlearning*: Microlearning encourages just-in-time learning in small steps with the aid of small learning units. It aims to quickly provide information to close knowledge gaps without interrupting the employees current activities for a long time [dWR13].
- *Game-based Learning*: In game-based learning, learning is motivated by the satisfaction of the need for competition, socialization or recognition. The required skills and knowledge are gradually built within the repeated gamecycle.
- *Learning in Simulation, Virtual 3D World and Immersive Learning Environment*: In these scenarios, the learning process takes place through an interactive learning platform with direct feedback. Virtual 3D can serve as a simulation of the environments, events or processes of reality [Hö13]. While in immersive learning environments, the user is located in the real environment which is extended with virtual elements or digital information.
- *Self-directed Learning*: Knowles defines Self-directed learning as " the process by which individuals take the initiative, with our without the assistance of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes" [Kn75].

2.5 Automatic Customization and Adaptation

The use of digital technologies provides high potential for customization and adaptation of the learning process or content to the learner skills and needs.

- *Context-Aware/ Pervasive Learning*: Context-aware learning systems detect the user context by collecting information about the physical environment through sensors data and adapt the system based on this information [LR14].
- *Adaptive Learning*: In adaptive learning the learning system adjusts the learning content and steps based on the learner current and historical performance. Next learning steps are proposed based on measuring different parameters that characterize the learner performance and comparing it with other learners.

2.6 Technical Competences

This work primary focuses on workplace learning in manufacturing and digitized industry. Competences needed in this field can be distinguished as follows:

- *Operating*: Workers responsible for operating a machine should have deep understanding of the process and be capable of keeping the machine running under normal production conditions.

		APPsist	KOLA	LAYERS	Plant@Hand	PLuTO	MoLeApp
Competence Level	Assembly & Manual		✖	✖	✖		✖
	Controlling	✖		✖			✖
	Maintenance	✖		✖		✖	✖
	Operating	✖		✖			✖
Customization	Context awareness	✖			✖	✖	
	Adaptive Learning	✖					
Learning Methods	Self-directed Learning			✖	✖		
	Simulation, virtual 3D world & Immersive Environment				✖		
	Game-based Learning						
	Microlearning	✖		✖		✖	✖
	Mobile and Ubiquitous Learning	✖	✖	✖	✖	✖	✖
	Social Learning & Collaborative Learning		✖	✖	✖		✖
	Distance & Web-based Training & Blended Learning						
Instructional Model	Exploration				✖		
	Articulation & Reflection		✖	✖	✖		✖
	Scaffolding	✖					
	Coaching	✖	✖		✖	✖	
	Modelling	✖	✖	✖	✖	✖	✖
Work-related Learning	Learning Activities Located within the Processes			✖			
	Learning Processes at or near the Workplace		✖	✖			✖
	Work Processes with Learning as a By-Product	✖			✖	✖	✖
Job Type	Engineering	✖	✖	✖		✖	✖
	Work craft			✖	✖		
	Non-routine						
	Routine	✖	✖	✖	✖	✖	✖

Tab. 1: Clustering of the examples presented in this survey

- *Manual and Assembly Work*: Assembling is a manufacturing process in which workers have to fabricate and join parts to construct the final product.
- *Controlling*: Controlling includes proactive actions and operating the machine during normal and exceptional production conditions. Thus detailed knowledge of the dependencies between the machine's individual components is needed.
- *Maintenance*: Maintenance describes the process where a worker undertakes the required actions to repair and conserve the machine operations under near normal conditions. Thus detailed knowledge of the machine individual components dependencies on each other is needed.

3 Exemplary Classification

With respect to the pedagogical, technical and didactic concepts described in the previous section, six assistance systems and learning platforms will be introduced and categorized based on the proposed scheme in Table 1 . APPsist project [Ul15] proposes a new mobile, context-aware and intelligent-adaptive assistance system for knowledge and action support in the Shopfloor. The joint project KOLA [He15] is aiming to orientate the professional training of the various learning locations to provide the necessary skills for the work process. KOLA focuses on offering the trainees a demand-oriented companion and reducing the learning gap or separation between different locations. PLANT@HAND [AB15] introduces a self-directed assistance system based on the model of cognitive apprenticeship for the industrial assembly workplace. PLuTO project [BR15] is concerning the demographic changes by ensuring the experience of older employees over their entire life cycle through recording and exchanging episodic knowledge between older and younger employees. The joint project LAYERS develops mobile and social technologies that support informal learning in the workplace for Small and Medium sized Enterprises (SMEs) within regional innovation clusters. Finally, MoLeApp project [Ja14] focuses on supporting mobile learning processes in technical vocational education using competence snippets instead of comprehensive materials.

4 Discussion and Future Work

This work proposed a first classification scheme which highlights the different terms and concepts characterizing learning systems at the digitized workplace. The classified approaches show that mobile, social and microlearning are currently the trends for gaining new knowledge, skills and experience at the workplace. Additionally, the selected solutions focus on work activities which are characterized by moderate to high analyzability while a shortage in research regarding non-routine and crafted work is recognized. In future work, using the addressed criteria, a comprehensive overview will be provided of the existing assistance systems and learning platforms as well as current research projects in light of the recent advancement in Multimedia-based learning environments. Furthermore, challenging or disregarded fields will be highlighted to encourage future research in the field of vocational training in the context of the new manufacturing revolution.

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