WORKING AND LEARNING IN INDUSTRY 4.0 ENVIRONMENTS

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Virtual engineering combines the fusion of physical and virtual realities, perceptions and communication with the use of (new) engineering methods in real time. This has a fundamental impact on current development and production processes. Physically non-existing objects can be experienced in a realistic and user-friendly way. The human being takes up information with all five senses simultaneously and reacts to it with speech, actions and body language.

Based on examples and results of the TELL ME Project "Technology Enhanced Learning. Living lab for Manufactory" the paper intends to show how the communication of the product with the user, the service person, the assembler etc. will take place in such a digitalized, highly networked environment in the future and describe the effects on Learning and Teaching. The authors of this paper have taken up the results of TELL ME and worked on two central questions: what consequences can be drawn from it regarding learning and teaching in digital laboratories and what transformation processes are imminent in university education.

Keywords: Industry 4.0, digital learning environments, Technology Enhanced Learning (TEL), Qualification needs

1. Introduction

The digitalisation of the workplace environment is progressing faster than ever and is leading to the penetration of information and communication technologies (ICTs) in all areas of life and work. In the associated technical vision, the physical world merges with the virtual world to form Cyberspace. "Cyper-Physical Systems (CPS) are emerging as part of a future globally networked world in which products, devices and objects interact with embedded hardware and software across application boundaries. [...] Cyber-Physical Systems links the physical world with the virtual world to form an Internet of things, data and services." [1].

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This development is referred to as the fourth industrial revolution or industry 4.0 and marks the paradigm shift in the networking of intelligent production technology, in which the Internet of Things (IoT) and the Internet of Services (IoS) play a central role [2]. "By connecting people, objects and systems, dynamic, real-time-optimized and self-organizing, cross-company value creation networks are created that can be optimized according to various criteria such as costs, availability and resource consumption [3]. The virtual and real worlds thus merge.

In this context, one also speaks of the beginning of the era of Smart Anything, characterized by the miniaturization of microcontrollers and microcomputers through which intelligent objects are created for an Internet of Things and used in the Smart Factory. "The real-time tracking of production processes enables the diagnosis and optimization of technological processes, so that information can be exchanged more effectively, and production becomes more efficient in the medium and long term" [4]. In an intelligent factory, the work content of employees is revolutionized from the ground up, which inevitably leads to a change in the role of people. Characteristic for this are, among other things, "the stronger support of the user through improved and mobile access to production data and equipment, combined with a user-centred and context-adaptive interaction design" [4].

In this environment, people simultaneously absorb an enormous flood of information with all their senses and react to it with language, actions and body language. Previous working and learning traditions have to adapt to this changed reality and this goes hand in hand with the central question of how learning and teaching should be structured in the future. With regard to this question, there is a high relevance of the results of the TELL ME project (Technology Enhanced Learning. Living lab for Manufactory), which is concerned, among other things, with this issue:

- how in an industry 4.0 environment the communication of the product takes place in a highly networked environment with the user (i.e. the user, the service person, the fitter etc.),
- which training methods can be used for the training, and
- what role the trainer/teacher or the user/learner plays in this context [5].

Based on training methods developed in the project and the analysis of the respective work and learning steps, this article formulates a desideratum for developing specific teaching methods.

2. Definition approaches: Virtual Reality (VR) and Augmented Reality (AR)

Terms such as Virtual Reality (VR) and Augmented Reality (AR) shape the public discourse, but their meaning remains relatively open. They are only concretized in relation to a context, for example an industry or a discipline. The term virtual reality was first used in 1989 by computer scientist Jaron Lanier in connection with device developments in 3D real-time computer graphics [6]. The novelty was that the content of virtual reality could be changed in real time, depending on the user's interaction. This interaction possibility is also referred to as human-machine interface, "[...] which, compared to traditional user interfaces, enables a particularly natural or intuitive interaction with the three-dimensionally simulated environment" [7]. Virtual reality is therefore a computer-generated phenomenon in which various technologies are used and whose core elements include both the user-centred view in a three-dimensional environment and multisensory response, interaction and immersion [8], [9]. Here three categories of reality experience are distinguished: passive, active and interactive participation, whereby the degree of immersion plays a decisive role because it is closely associated with the degree of user interaction [7].

In digitized environments, both virtual and augmented reality are used. In contrast to Virtual Reality (VR), Augmented Reality (AR) combines virtual and real objects. The current section of reality in the field of vision is searched for reference patterns, "[...] which represent the object of description and can consist of simple image templates (image/marker tracking) or spatial reference objects of point clouds or CAD-based edge models [10]. In the case of a match, the object of description is thus in the viewer's field of vision, which is superimposed with virtual image content. At the same time, the tracking process is initialized, and the position and size of the AR objects adapt to the continuously changing viewing positions of the viewer in real time.

3. Digital Learning Environments in Virtual and Augmented Reality using the example of the TELL ME Project

The European Union-funded research project TELL ME on workplace learning in smaller industrial 4.0 manufacturing environments (2012-2015) offers innovative training methods in a real-time learning environment exemplary for the textile, furniture and small aircraft industries [11].

It is an experience-based and result-oriented training in an industry 4.0 defined workplace, adapting the existing relevant e-learning and blended learning models, including action- and competence-oriented teaching and learning as well as participative learning methods in Living Labs [5]. Embedded in it is a coherent and integrative framework for lifelong learning in industry 4.0 environments to acquire new knowledge and competences and share them with other users. Users use a variety of devices such as PCs, laptops, tablets, smartphones, smart watches, data glasses, etc. in this training. In the system one can access different roles, be it as trainer, craftsman, process responsible person, system administrator or the like [5].

Among other things, process-oriented technical and web-based training approaches were developed for the learning environment at the workplace, as well as a personalised lifelong and autonomous learning system tailored to the needs of the individual. The technology platform developed for this purpose - ARgh! - forms the framework for this authentic learning and working environment and closely interlinks the two areas [5].

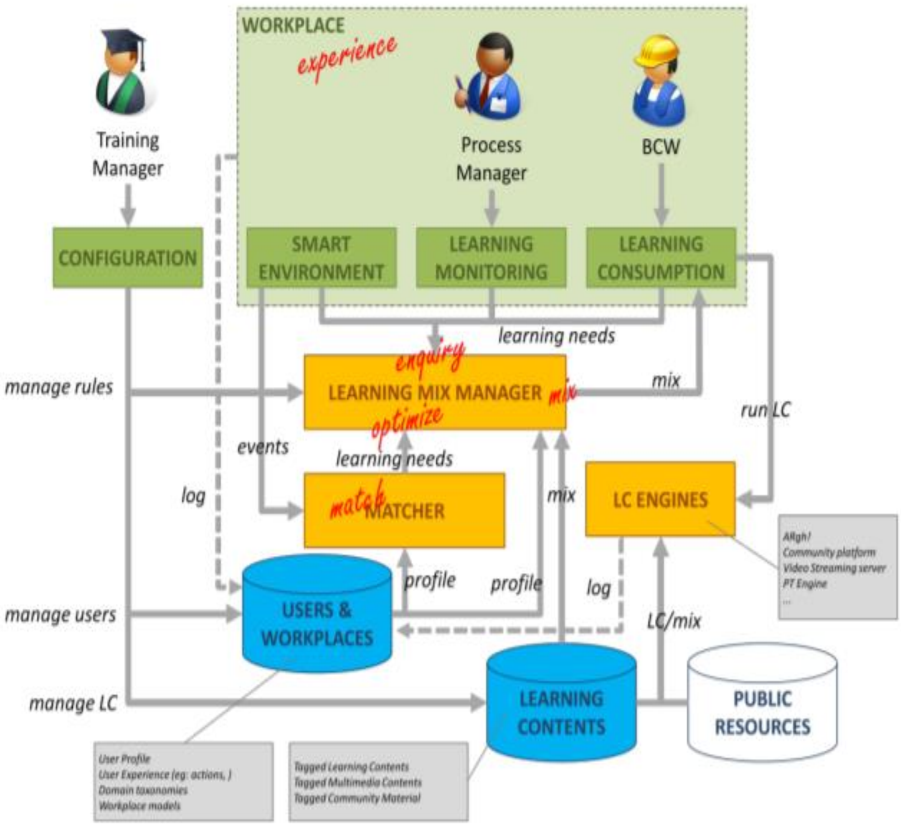

Fig. 1: TELL ME logical architecture with mapping on eMEMO training methodology [5]

In particular, the technology-based workplace scenarios and training concepts in the three above-mentioned industrial sectors, the embedded case studies and experience-based learning in intelligent assistance systems create a suitable basis for working out exemplary needs in Teaching and Learning.

Possible fields are vocational training, technical language instruction in adult education, e.g. in further training of employees and in post-qualification, but also at universities, which will be discussed in more detail here later.

3.1 A Learning Process Model in the Intelligent Factory (eMeMo)

The core element of the TELL ME system for workplace training is a cyclic five-phase model, which is referred to in the project as the eMeMo learning process model. It consists of the phases "inquire", "mix", "(learning) experience", "match" and "optimize" [5].

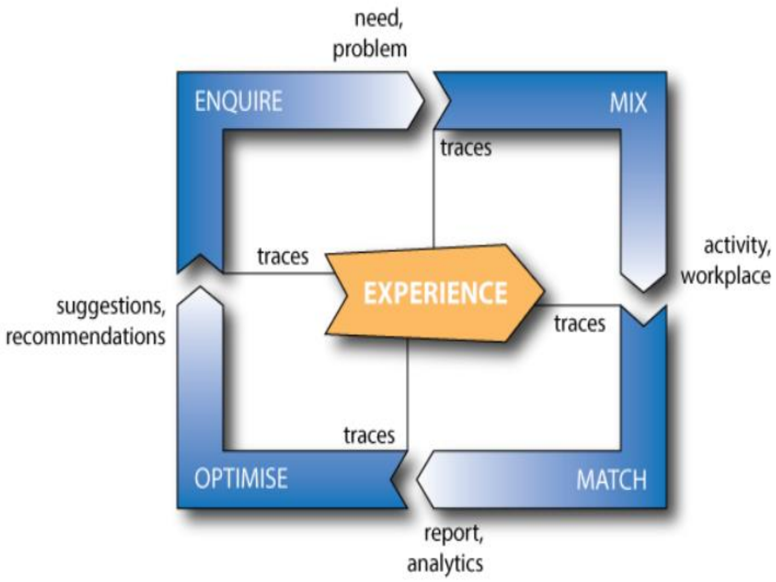

Fig. 2: The eMEMO learning process [5]

It enables the trainer to call up the appropriate content for the training needs defined by him or her, which is tailored to the learning needs of the user taking into account his previous knowledge and skills. In principle, each training unit can be repeated or recompiled as often as required if further gaps in knowledge arise during the training [5]. The decisive factor here is that the three methods "Learning by Imitation", "Learning at Fluency" and "Learning by Doing" are always embedded in the learning process in the respective specific "mix" and thus control the learning process.

Fig.3: The eMEMO learning process [5]

Any number of combinations can be generated depending on learning needs and learning objectives. The specific combination represents the work area or learning space. In order to facilitate the creation of the learning combination for each specific learning situation, the learning contents are described and classified in the TELL ME system [5].

During the training phase, learning combinations are first made available to the user, to activate previous knowledge, close gaps in knowledge and therefore serve to relieve the previous load on the training module. The learning process and learning outcomes can be tracked and evaluated at any time. During the processing time, blended learning activities take place at and outside the workplace, for example

- to read the general safety instructions on the tablet,
- to call up the workplace with the Augmented Reality app and familiarize yourself with a new manufacturing process,
- to perform a guided step-by-step activity at the workplace freehand using the electronic work card, and finally
- to consolidate the acquired knowledge by deepening tasks [5].

The "electronic work card" is equipped with extended reality environments on mobile devices and supports the user at every step: It provides information on request and guides him step by step through the working and learning process [5]. A feedback system provides the user with information on the training activities he/she has carried out and on the effectiveness of his/her learning progress. In addition, the user can comment on the training modules as well as refer to comments of other users or rate them. [5]. For the tracking of the learning process, so called connecting strings, which are collected about the current activity and context, are important, because they provide valuable data for each interface. The adaptation is also decisive in this process, since the filtering and analysis of the data takes place here in particular [5]. If immersive and interactive workplace training is required (e.g. to familiarise employees with new processes or to train new employees), "learning-by-doing" can be supported by an augmented reality app, in which the workplace is automatically enriched with information (e.g. safety information on materials, equipment, machines, etc.) and learning content according to the workplace profile and the needs of the employee [5]. In addition, the system provides an environment for social interaction so that users can share ad hoc information (e.g. texts, images, audio, videos) with others as well as build a professional virtual social community together. In addition to the exchange of information, this environment also serves the creation of training materials and offers the possibility of both formal knowledge exchange (e.g. through moderated forums) and informal exchange [5].

3.2 Application of Augmented Reality (AR) and the Internet of Things (IoT) at the example of workplace training (TELL ME Project)

As described in Chapter 2, Augmented Reality combines virtual and real objects in the Industry 4.0 environment, where the Internet of Things (IoT) and the Internet of Services (IoS) are the critical interface. The example taken from the TELL Me project will illustrate this process flow in the following.

The test object acting with the system contains a two-screen system with active stereo 3D sound system and optical tracking system. The manipulated objects are realized as IoT control boxes and as devices. A tablet connected to the server for the use of the "- Argh! Platform" provides the data and work tasks. All extended IoT information and IoT symbols are visualized on the tablet [5].

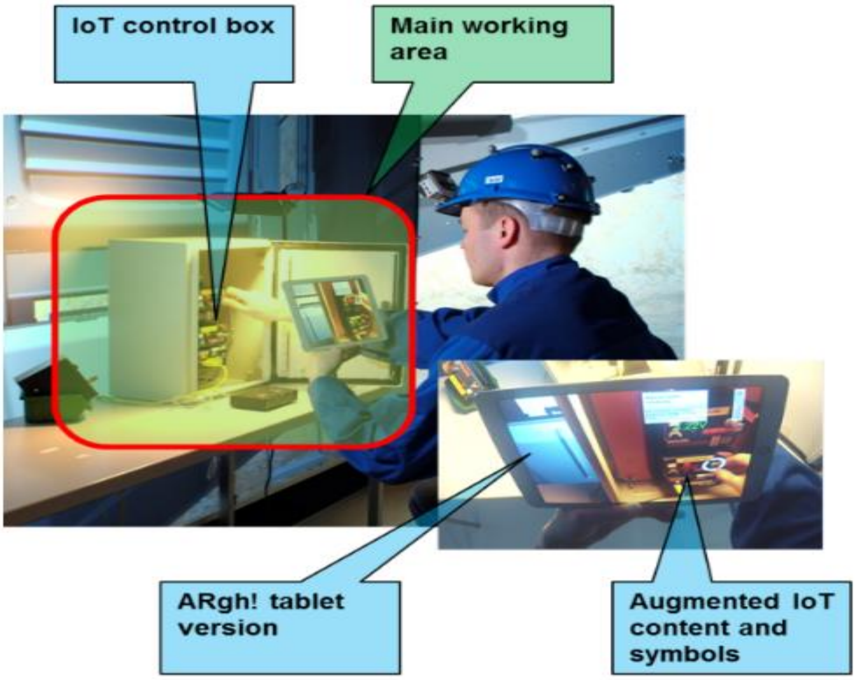

Fig. 4: Training at the workplace [5]

Using his electronic work card, the user receives instructions on his tablet that enable him to track and react to changes in the IoT control box using image-based tracking. At the same time, the voltage values of the modules are displayed in real time [5]. All elements are optically highlighted by a text box. If required, the user can add his remote trainer to this workflow at any time. He is connected to his remote trainer in real time, sends his context data via the camera and can communicate with him hands-free with the help of speech recognition and receive feedback in real time. The implicit knowledge of the user is already recorded in the TELL ME system, i.e. activities previously carried out using mobile devices were stored in the knowledge base database with the aid of an activating camcorder.

This working and learning environment is to some extent present in digitized laboratory environments in university teaching, but also in vocational training, and will expand considerably in the coming years, not only in industry 4.0 disciplines, but far beyond. It thus poses enormous challenges for the education system to date, which will be discussed in more detail in Chapter 4.A

3.3 Results of the TELL ME learning process model

The Tell-Me system supports the user in getting assistance as needed, which accelerates the learning and working process using the AR modules and at the same time makes a significant contribution to error avoidance. The project results show that especially action- and competence-oriented learning using Augmented Reality was rated by the employees as very important for their learning process and had positive effects on their professional and media competence [5].

From the point of view of managers, this learning process model offers a great advantage for employees. However, they consider this added value for their own work to be rather low [5]. Therefore, it can also be concluded from this that this training platform appears to be more suitable for activities in the product life cycle.

4. Qualification needs for Industry 4.0 in Higher Education

The study by [12] on the "Effects of Industry 4.0 on Initial and Continuing Vocational Training" presents four technological dimensions of Industry 4.0 and estimates the resulting changes in qualification requirements. Here it becomes apparent that a derivation at the level of technical knowledge or operating knowledge is too short if the actual requirements are to be determined in a target-group-specific manner. The estimation of the four technological dimensions of industry 4.0 included, among other things, the analysis of the following three questions:

- What exactly is the technical qualification requirement?
- Which target groups are affected?
- What institutional challenges are involved? [12]

These questions can best be answered by looking at "... the strength of change at the level of work equipment, the object of work and work organisation" [12]. Another central aspect is the dimension of the complexity of the overall system, which leads to new technical requirements.

When determining requirements, it is also important to find out how strongly the realisation of technical solutions demands "a participative design by the employees", because "the more systemic the innovation is and the more comprehensive the impact of change, the more it is necessary to involve the employees and their specialist and experience knowledge from the outset" [12]. If it emerges from the analysis that a change at the level of work equipment, work objects and work organisation take place through industry 4.0 approaches, then this is a reliable indicator for emerging qualification requirements. These must first be determined in terms of content, so that the necessary formats and forms of qualification can then be defined [12].

Pfeiffer emphasises here that for the successful implementation of the qualification requirements "the contribution of experience and living working capacity" must also take place in the form of early participation of the employees [12], because

A. the methods of teaching are more relevant than the technical contents, especially since these will change faster than before. "From the very beginning of initial training, it will be necessary to develop people who think for themselves and are capable of acting independently [12].

B. social skills will become even more important in the future. Because soft skills for teamwork are only a small part of the competencies. Rather, the ability "to collaborate inter- and transdisciplinary (i.e. across several disciplines and with other departments, companies, customers and/or civil society)" and systemic thinking is required [12].

C. the "methodological forms of learning and the early involvement of employees in the design of industry 4.0 via participative processes [are] decisive in two respects [...]: firstly for the design of better technology and better work, secondly because a large part of the necessary learning and experience processes take place in the Doing [12].

The results of the study prompted Pfeiffer to call for measures to make skilled work and the vocational system of initial and continuing vocational training more attractive.

Regarding higher education, it recommends that:

- at all levels of qualification and in particular at management level "to define learning objective as competences for qualified handling of power and of data limits", in technical subjects, in economic disciplines and in teacher training [12].

- to expand "the knowledge of participation processes and the associated methodological competencies" in engineering sciences and information technologies by incorporating theoretical and methodological knowledge into corresponding approaches (workplace, innovation, social innovation, action research, design thinking, agile methods, etc.) in the curriculum [12].

- Offers for the training of future executives, such as the further training of existing executives at universities, should be expanded with a strong focus on participative leadership styles and democratic forms of enterprise [12].

- new subject contents "to clarify in which occupational profiles or which study programmes the imparting of the corresponding specialist knowledge is to be included" and "when they are to be integrated sensibly as a fixed component in selected technical occupational profiles and study programmes". In view of the dynamics of the new development, this step must be taken more quickly than has been the case to date, whereby for Pfeiffer the "actual qualification requirement is to use the existing design options proactively, above all with regard to teaching staff at universities and vocational schools and in companies" [12].

- to use the potential of the Internet of Things/3D printing in the new robotics and additive processes, especially since this is a "technology that can be live and experienced", which has come to light through the movement of the makers, the FabLabs and the DIY (Do-It-Yourself). This kind of enthusiasm for technology should be taken up in any case, because "vocational schools or training workshops offer technically everything that FabLabs needs in terms of technical equipment - completely new and innovative ways of cooperation between industry, public authorities and civil society could be treaded here. [...] On the one hand, this would offer the opportunity to win over young people at an early age and in more appropriate forms for technical training paths and, on the other hand, to introduce older teaching staff to the technologies that are new for them through cooperation with the Maker movement, so to speak, in doing"[12].

4. Conclusions

More authors [12], [13] and [4] stress the societal transforming potential of industry 4.0 and point out that the complexity of the challenges should be addressed inter- and transdisciplinary. They call for vocational education and training that focuses on people, namely on their participation and orientation in the further development of industry. The current discussion would only be application-oriented and would mainly deal with qualification needs from a technical point of view and with economic aspects. The subject of discussion should include all areas of life and the circle of actors should be as broad as possible. "Since industry 4.0 is above all a design topic, it is much more important than before that designers and users learn to talk to each other in participative processes: Employees must formulate their demands to IT developers and be able to argue about them. And conversely, IT developers and plant planners must learn even more than before how to include the needs of employees and their customers earlier in the development process." [12].

The Acatech working group Industry 4.0 defines eight relevant fields of action, which also include work organisation and work structuring as well as training and further education [15]. Both the analyses and the study by [12], [15] show that the changed requirement profile for employees - working more responsibly, more flexibly and more independently - requires intensive training and further education. Transversal competences at all working levels, new forms of learning and teaching are in demand here. This includes the future understanding of the training occupation, the further development of regulatory tools, the relationship and transitions in initial and continuing vocational education and training, vocational education and training and higher education, as well as the design of learning processes, the use of teaching and learning materials and the role and qualifications of training personnel [15].

In the further development of industry 4.0, the demands on systemic thinking and interdisciplinary cooperation will increase sharply and a large number of employees outside the IT world will need more understanding of IT and data structures. In addition to production technology know-how, the handling of data will also be the subject of formal qualification. “It will primarily be a question of relating offline and online to one another.” [12] The examination of data protection and privacy will also be indispensable, as will knowledge of the power and limits of algorithms, for example in order to understand the differences between causality and correlation [12].

All the studies mentioned [16], [17] on Industry 4.0 postulate the need for research in order to provide more clarity as to which future educational needs will arise in this context. Only then can the corresponding standards for professional, methodological, social and personal skills be derived [4]. What employees must be able to do in the future is still an open question, especially since this is due to the development of the respective reality of industry 4.0 [18].

Based on the working and learning environment in the TELL ME project, we have nevertheless tried to point out a number of general features that have to be taken into account in the design of Teaching instruction, namely based on the questions of which features exist in the working and learning environment in industry 4.0 or in networked systems and which working and learning steps could be derived from them.

Main characteristics of the work/learning environment in industry 4.0 are the following:

- In a highly networked environment, the work/learning steps run in parallel and are largely processed in real time. Experience-based learning is part of this process.
- The corresponding work/learning object is physically present and is also virtually visualized via the data goggles or notebook/smartphone. All further information required in this context can also be called up directly via the data goggles.
- Due to the combined analogue and virtual environment and the access in (almost) real time to all relevant information, the learning process is accelerated.

- Visualization form (physical as well as virtual) is the representational level, i.e. the degree of abstraction is low and makes understanding easier for the users/learners. This is a great advantage, which makes the Teaching in Foreign Languages more designable, especially at A1 and A2 level.
- And last but not least, systemic thinking is required at all levels.

The TELL ME training model is a very vivid example of how learning and working by doing and through experience takes place and what changes are in the offing in the tertiary sector. This requires an interdisciplinary form of work across all disciplines, cooperation with industry and other actors who play a key role in the transfer towards the digital age.

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