Towards Industry 4.0: Leveraging the Internet of Things for Workplace Learning and Training

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Abstract. New technological developments, like the Internet of Things (IoT), wearables and augmented reality, bring a lot of potential for the improvement of workplace learning and training on the way towards Industry 4.0. However, in addition to the new opportunities, there are also accompanying risks and challenges to overcome. On one hand, there is a strong requirement for retraining and upskilling of the workforce, on the other one the employees should be motivated for this change, possess necessary metacognitive competences for professional development, but also understand and trust the decisions provided by machines. This is closely related to the control of privacy by each individual. Researchers and developers address these issues from various perspectives. Some developed user modeling framework for IoT applications or model psychomotor activities. Others use smart technology to support training of practical skills, awareness and reflection by means of learning analytics, as well as guidance of users through useful nudges. Here we want to point out several of prospective approaches that aim to address the outlined issues. Finally, we attempt to discuss the impact of IoT on workplace learning and training as well as to offer a vision on emerging challenges and opportunities.

Keywords: Workplace Learning, Professional Development, Industry 4.0, Internet of Things, Personalized Training.

1 Introduction

Humans always invent tools in order to make their life easier and their work more efficient. These tools then change them, as experiences change the brain throughout the life course (Doidge 2007). The information and communication technologies (ICT) are no exception and there are serious warnings regarding their impact on our brains (Carr 2011), as every medium develops some cognitive skills at the expense of others (Greenfield 2009). But the long term effects may be very difficult to predict, especially considering the rapid development of these technologies. This raises serious concerns.

On the other side, there are certainly unique new opportunities how to use ICT for the benefit of people, when we know what we are doing and keep the technological development under control. A proper analysis and interpretation of the big data in the educational area can improve our understanding of learning processes as well as effectiveness, efficiency and attractiveness of learning and training at the workplace, making them more authentic and thus also more motivating, which is crucial. Another important aspect is a better understanding of the user needs and objectives that should enable a higher quality in personalization and adaptation of learning and training experiences, as well as cultivation of metacognitive skills.

The Internet of Things (IoT) is "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies" (ITU 2012). It can bring a better understanding of the users, their current status (including attention, emotions and affects) as well as their context. Together with wearable technologies (WT) and augmented reality (AR) they can substantially enhance the usage of human senses in order to learn new knowledge and train new skills.

In the following we first clarify our motivation, describing the problem being addressed as well as its importance. Afterwards we outline the current state with the related limitations. Then several technological and pedagogical approaches are introduced. Finally, we try to foresee the impact of these developments, considering relevant challenges and opportunities.

2 Motivation

The problem of professional learning and lifelong competence development is not new. The first author personally had the honor to participate in several European projects that addressed this issue from various perspectives. In PROLEARN the consortium dealt with interoperability of personalized adaptive learning (Aroyo et al. 2006) and later on also with social learning (Klamma et al. 2007), among other objectives. TENCompetence focused on competence management and informal learning in communities of practice. The aim of iCoper was content interoperability and standardization in the area of learning. Then in ROLE the team supported Self-Regulated Learning (SRL) by means of responsive open learning environments (Nussbaumer et al. 2014). This technology was later used in BOOST in order to help managers and employees in SMEs with identification of knowledge gaps in companies and filling them by suitable offerings in personal learning environments (Kravcik et al. 2016b). In Learning Layers the main focus was on the scalability issues (Ley et al. 2014), also by providing meaningful learning via adaptive video (Kravcik et al. 2016c). The challenge in WEKIT is to provide novel training opportunities at the workplace with a help of wearable technology and augmented reality (Guest et al. 2017). Finally, in ADAPTION participants are dealing with requirements of companies on their way towards Industry 4.0, including development of their personnel (Kravcik et al. 2017).

Although a lot has been done in these and many other related projects, the current situation at the real workplace from the learning and training perspective is certainly not satisfactory. The first and perhaps the most important issue is the motivation of companies and employees to perform such informal education (Kravcik et al. 2016b), for which authenticity is a key aspect. Companies will most probably prefer it over more formal alternatives for the cost reasons, but they need user friendly, effective, efficient and attractive tools, which bring them a clear benefit and added value in comparison with generally popular applications. The provided tools need to be flexible and customizable for various learning objectives and settings, as well as personalized and adaptive, in order to provide individualized learning experience, taking into account also the current user status and context (Dolog et al. 2007). Moreover, other crucial requirements include scalability, reusability, interoperability (Aroyo et al. 2006) and easy authoring. Support of communication, collaboration and social media is a must. Wearable technologies and augmented reality can bring a qualitative breakthrough into training of skills in the authentic workplace environment, enabling immersive procedural training like capturing and re-enactment of expert performance.

The described problem is important for various reasons. The trend of automation and data exchange in manufacturing technologies, called *Industry 4.0*, impacts the organizational processes as well as the role of the employee. Companies need to identify their competence gaps and fill them efficiently. Employees can have their own aspirations regarding their lifelong professional development and plan them accordingly. Moreover, there is also the interest of the whole society to reduce the unemployment rate and make people happy doing the work they like and understand.

These rather general requirements are now being transformed into the new circumstances of the transition towards Industry 4.0, which is a big challenge. The existing centrally and hierarchically organized structures in production enterprises will be increasingly decentralized in the future. There is a paradigm shift from the prevailing resource-oriented planning to a product-oriented planning (Wahlster 2014). The organizational and technical changes imply regularly updated and dynamic competence profiles of employees, requiring requalification through new learning formats directly at the workplace. This development calls for increased communication skills, an increased degree of self-organization, as well as new abstraction and problem solving competences (Straub et al. 2014). Cooperation with robots will be another important skill in the near future.

3 Current State

Learning and training services are based on the data that has been collected about the user status and about the current context. IoT consists of identifiable objects that can communicate and interact (Mionardi 2012). They use sensors to collect information about their environment and actors to trigger actions. Although not all technical challenges of IoT have been already solved, the technology can be used as enabler for research. In the area of education, the early work with IoT focused on recognizing an object, presenting its information or activities (Broll 2009), as well as social interaction on objects (Yu 2011). So there is still a lot of unexploited potential of IoT in this field, especially beyond the technological perspective.

But there are also research fields that consider pedagogical point of view in a more advanced way. *Educational Data Mining* aims at automatically extracting meaning from large learning data repositories. Supporting reflection on the learning process in a flexible way can be facilitated by suitable *Learning Analytics* tools, visualizing both long term- and short-term behavior of participants. Nevertheless, various degrees of privacy and data security have to be provided, to allow different levels of integration, depending on special preferences of individuals and other bodies, like companies (Kravcik et al. 2016a). It is crucial to take into account relevant pedagogical models for learning at the workplace, like the one focusing on scalability (Ley et al. 2014). Novel pull models of informal learning are required, which facilitate creation of knowledge during the execution of the learning process (Naeve et al. 2008).

Assistance and knowledge services are defined as software components that provide specific types of support: assistance services assist in solving a current problem, while knowledge services support the transfer of knowledge, it means the achievement of individual medium- and long-term development goals (Ullrich et al. 2015). The current state of the art is represented by service architectures whose functionality results from the interplay of a large number of services. Each of the services thereby implements a specific, independent functionality and makes these available for other services. One of the most advanced service architectures has been developed in the APPsist project for industry 4.0 (Ullrich et al. 2016).

Personalization of learning experiences deals with such issues like effective detection and management of context and personal data of the learner, considering also their emotional status (Santos et al. 2016). A better understanding of the person can be achieved by processing information from various resources (e.g. wearables with physiological and context sensors) and related big data. Learner’s preferences change dynamically, therefore available sensors can help significantly in their recognition. Collected sensor data can help to infer contextual preferences based directly on the individual’s behavior (Unger et al. 2017).

Metacognitive skills, like Self-Regulated Learning (SRL), are crucial for the effectiveness of lifelong learning. Therefore, the employed technologies need to cultivate them, providing a right balance between the learner's freedom and guidance. This should stimulate motivation, while considering also the effectiveness and efficiency of the learning experience (Nussbaumer et al. 2014). Effective support for SRL includes integration of nudges and reflection facilities in a suitable way (Kravcik & Klamma 2014). Awareness and reflection services can provide valuable feedback, if they interpret and visualize the collected data meaningfully and in an understandable form. Regarding this, technology designers and developers have to incorporate knowledge from various fields, including psychology, pedagogy, neuroscience and informatics (Kravcik et al. 2017). Open Learner Models (OLM) show the learner model to users to assist their SRL by helping prompt reflection, facilitating planning and supporting navigation (Guerra-Hollstein et al. 2017).

The usage of adaptation and recommendation services in learning is limited, if they are not understandable and scrutable, which is a usual problem when Artificial Intelligence techniques like Deep Learning are employed (de Bra 2017). Machine made decisions should be explainable by rules or evidence, in order to raise the trust of users. These need also clear and manageable privacy policies, in order to feel their control (Colbeck 2017).

4 Vision

From the technological point of view, we can distinguish four layers of services. At the bottom the *data* layer, where a fusion of data from IoT sensors takes place. Then the *platform* layer, where the data analysis is being performed. Next is the *services* layer with multimodal assistance and knowledge services. On the top the *user interface* layer offers personalized and adaptive learning and training experience with wearable technologies and augmented reality.

At the *platform* layer there will be support for user modeling to harness and manage personal data gathered from IoT (Kummerfeld & Kay 2017), which will help IoT application developers to achieve light-weight, flexible, powerful, reactive user modeling that is accountable, transparent and scrutable (Kay & Kummerfeld 2012). Related approaches will deal for instance with elicitation of human cognitive styles (Raptis et al. 2017), affective states (Sawyer et al. 2017), as well as modeling psychomotor activities (Santos & Eddy 2017).

The *services* layer will provide relevant awareness and reflection indicators (Kravcik et al. 2017) as well as guidance like nudges (Dimitrova et al. 2017). New useful services will be created, like meta-adaptation providing adaptation strategies according to learning objectives (Kravcik et al. 2016c). Assistance and knowledge services will incorporate various levels of interaction. Based on the user behavior and its analysis they can simply provide feedback in the forms of hints, nudges and recommendations, letting the user decide which of them to consider and accept. On the other hand, they can conduct an intelligent dialogue with the user, responding to their questions and input. The workplace and informal learning will be enhanced with new complementary combinations, like enhancing micro-learning offers (nuggets) with learning recommendations (nudges). While the former typically represent small segments of content, the later can be useful in driving learning processes.

The *user interface* layer will offer new opportunities for immersive procedural training, like capturing and re-enactment of expert performance, enabling immersive, in-situ, and intuitive learning (Guest et al. 2017). Motor skill learning is another area where wearable technology and user modelling will be synergistically combined (Dias Pereira dos Santos et al. 2017).

IoT is decentralized and can provide greater privacy and security. Here the blockchain technology (Tapscott & Tapscott 2016) plays a crucial role, as it allows devices to autonomously execute digital contracts and function in a self-maintaining, self-servicing way. This new paradigm delegates the trust at the object level, enabling animation and personalization of the physical world. It will provide novel refined facilities for users to control their privacy and protect their data. Blockchain will disrupt education, replacing the broadcast model with preparation for lifelong learning, cultivating relevant competences, like critical thinking, problem solving, collaboration, and communication (Tapscott & Tapscott 2017).

5 Future Prospects

Transition of companies towards Industry 4.0 is a complex process, which is very difficult to control. Nevertheless, it is important to search for solutions that can make this move easier for both parties involved – the companies themselves and their employees. Each of them needs a good motivation and a clear benefit when new tools and services are to be adopted. This change will be certainly accompanied by many requirements for requalification, which calls for a radical improvement of informal learning and training at the workplace, based on novel pull models that support creation of knowledge in the learning process.

To summarize, learning and training offers should be based not only on individual preferences of users, but also on the effectiveness and efficiency of the learning experience, considering also the current context, including learner's emotional status and attention. New sensors and IoT open more opportunities for collection and analysis of the big data acquired in all learning processes. They can enable a better recognition of learner's objectives, preferences and context, which should lead to a more precise personalization and adaptation of learning experiences. Their effectiveness and efficiency can be improved by wearable technologies and augmented reality, which opens new horizons for novel training methods, cultivating required competences. Transparency and understandability of machine decisions as well as clear and manageable privacy rules are crucial to gain the trust of the user. These requirements can be facilitated by the blockchain technology, which has the potential to be the next disruptive ICT.

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