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Procedia Manufacturing 23 (2018) 189–194

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

8th Conference on Learning Factories 2018 - Advanced Engineering Education & Training for Manufacturing Innovation

A concept and local implementation for industry-academy collaboration and life-long learning

Minna Lanz*[a], Andrei Lobov [a], Kati Katajisto[b], Petteri Mäkelä[b]

[a]*Tampere University of Technology, Tampere, Finland*
[b]*Seinäjoki University of Applied Science, Seinäjoki, Finland*

Abstract

Global operations are accelerating the diffusion of technology and the pace of innovation. The increased demand for ICT and problem-solving skills requires new methods and tools to support continuous learning paradigm. The cornerstones of the OECD policy framework for developing a suitably skilled workforce are a broad availability of good-quality education, a close matching of skills supply to the needs of enterprises and labor markets, support for workers and enterprises to adjust to changes in technology and markets, and preparing for the skills needed in the future. The life-long learning is a challenge among the companies, especially among SMEs. As production systems become more complex and software-intensive, the workers often have to possess heterogeneous skills, so that the companies would be able to keep up with the challenge of building high added value products. In order to concretize the policy frameworks, we have developed a concept for enhanced industry-academia collaboration to support training in different levels of career. In this paper, we introduce a concept for collaboration, associated physical environment and examples of the activities so far.

Peer-review under responsibility of the scientific committee of the 8th Conference on Learning Factories 2018 - Advanced Engineering Education & Training for Manufacturing Innovation.

Keywords: learning environment, life-long learning, industry-academia collaboration, cyber-physical production system

* Corresponding author. Tel.: +358-40-8490278.
E-mail address: minna.lanz@tut.fi

2351-9789
Peer-review under responsibility of the scientific committee of the 8th Conference on Learning Factories 2018 - Advanced Engineering Education & Training for Manufacturing Innovation.
10.1016/j.promfg.2018.04.015

1. Introduction

Manufacturing plays a relevant role for keeping up the well-being society. The development of a talented workforce and trustful collaborative relationships with stakeholders, as well as a powerful technological and industrial base, are essential to address the challenges ahead and achieve high levels of employment and social cohesion, boosting at the same time innovativeness and competitiveness [13]. The population in the western countries is growing older and living longer. The careers are expected to be longer and more versatile. This trend will impact profoundly to the societal development in Europe. At the same time, the EU's workforce is expected to become smaller and older, but better qualified. The younger generation is the most highly qualified in Europe's history [3]. However, in globally, a surplus of low-skilled workers and a potential shortage of high-skilled ones are expected in near future [13]. Furthermore, the importance of both science, technology, engineering and mathematics (STEM), and ICT-related skills and "soft skills" grows for a large number of occupations [5]. OECD policy frameworks' cornerstones for developing a suitably skilled workforce are defined such as 1) broad availability of good-quality education as a foundation for future training, 2) a close matching of skills supply to the needs of enterprises and labour markets, 3) enabling workers and enterprises to adjust to changes in technology and markets, and 4) and anticipating and preparing for the skills needs of the future [11].

In recent years, analysis on employees' wellbeing highlights that more than in the past, an individual has to deal with different objectives, desires, expectations and responsibilities, which can be clustered in two main categories of work and life. According to [2], "dual-centric experience" provides "more overall satisfaction, greater work-life balance, and less emotional exhaustion", that organization should take care of employees as whole individuals in order to enhance their wellbeing. Still, the rapidly advancing technological landscape in the European workplaces is challenging adults' problem-solving skills. Workers with vocational education and training need flexible abilities to solve problems in technology-rich work settings [9].

The emerging technologies both push and pull the development of education. The movement from traditional education is slowly changing towards more interactive and problems solving-based learning [6, 9,10]. According to Lave and Wenger [12] learning is a process of social participation, in which novices move from legitimate peripheral participation and less critical work tasks towards gradually deepening participation and eventually full membership in the communities of practice. Engeström's [7] concept on expansive learning highlights the case where the expertise is not only collated in the communities of practice, but also in multiple interacting communities. Attwell [1] emphasized that personalisation can improve learning by empowering students to manage their learning at their own pace and with the technologies they use in a daily life. This can be achieved through the broad concept of a personal learning environment (PLE), which directly addresses the technical coordination problems of learners by providing the means to coordinate services from the institution with other services from the web. Chryssolouris et al [4] introduced a teaching factory concept for enhanced learning with hands on projects.

Wallin et al [14] described the elements for the expert learning in the future. These elements consisted four dimensions *1) Problem solving* consisting of introducing non-routine and practical problems, challenging to solve problems collaboratively, encouraging learners to acknowledge and solve professional identity issues; *2) Reflection* consisting stimulating critical reflection on learning and experiences, encouraging reconstruction of the meaning of experiences, promoting responsive guidance through mentoring; *3) Learning from errors*, which consist of helping learners to resolve tensions and develop flexible imaging, prompting epistemic process help to identify flaws in mental models, developing learners' time and resource management, promoting critical dialogue through collaboration and mentoring; and *4) Boundary crossing* that includes developing learner identity and adaptation, creating multiple opportunities for participation and learning, rationing university and workplace perspectives, explicating cyclical expertise development process between work and academic contexts.

In order to support the efficient training of future workers and life-long learning in different demographic conditions, there is a need for local operations. In this paper, we will introduce a versatile learning environment and operational concept how to facilitate collaboration between industry and academia and support the continuous life-long learning among local companies. The operational context of the companies is that they produce highly personalized high-value products in a high cost country, where the basic skills of the employees are highest among the EU-28. Paper is organized as following, the chapter 2 shows the research material and methodology, the chapter 3 introduces the learning environment and collaboration concept, the chapter 4 concludes the article with the summary of the findings and proposes future activities.

2. Methodology and Material

The research methodology in this work comprised a technology-oriented workshops with local companies and regional administrative in order to collect and prioritize the future needs related to the industrial sector.

Table 1. Collection of user requirements

No.	Goal and Objectives	Participation:	Date	Location
WS 1	Goal: To form best and worse scenarios for adapting or not IoT and CPS in SMEs.	12 industry, 3 academia	Week 2, 2017	Seinäjoki
WS 2	Goal: Identification what CPS-Services are needed to reach the best scenario; what is now available in the region	11 industry, 2 academia	Week 4, 2017	Seinäjoki
WS 3	Goal: To formulate the business plan of the hub to reach CPS in Smart Specialization and enabling the scenario based on results from WS 2	7, Other stakeholders, 2 academia	Week 4, 2017	Seinäjoki

Industrial stakeholders were composed of Competence Centres, Large companies, Manufacturing SMEs, CPS Solutions Providers, IT Innovation Providers, Regional / National Authorities, Banks, Finance Inst, Venture capitalists, Chambers, Trade Association, Clusters, Spinoffs, Spinouts Ecosystem and Experimental Facilities. The topics that were considered the most important by the local companies are classified in the Table 2.

Table 2. Classification of the user requirements

Technology	Education & learning	Business models
Technologies are available, the challenge is how to exploit them. Collaborative robotics is coming to shop-floor, this is completely new. Production simulation in optimizing production will become common along with the real-time follow-up of production. 'Field Agents' following technology development are needed.	SMEs need a new kind of IT-competences; are there enough talents and training available in the region? Life-long learning is both workers' and SMEs' responsibility; new forms for training are needed. Digital manufacturing and Internet of Things (IoT) are big game changers and need commitment (mindset) from managers at the shop-floor. Short webinars and workshops are preferable rather than long training courses. Benchmarking and learning from other companies.	Data analytics and ownership is a big question; new business models will arise from this field. Ownership of data and the contract jungle are challenging. Fast pilots before investment decisions.

Based on the user requirement workshops, the SMEs in manufacturing are concerned if in the future there will be enough experts in the digital manufacturing, industrial internet technologies, cloud-services and data analysis. They are not interested in long training programmes, but rather short courses, demos, pilot projects, immediate support and learning-by-doing possibilities. Based on the workshops and discussions with the local industry, a following classification, illustrated in Table 3, of occupational and personal competence profiles was generated.

Table 3. Classification for competency profiling, modified from [15]

	Occupational	Personal
Conceptual	**Cognitive competence (knowledge and understanding)** • Evaluating issues from various perspectives • Occupational awareness • Effective use of information • Conceptual and analytical abilities • Problem definition and solving skills • Analytical and reasoning skills, critical thinking	**Meta competence (learning to learn, coping with uncertainty)** • Metacognition • Motivation • Self-efficacy beliefs, Self-regulation • Empowerment • Life-long learning (study plan) • Intellectual development
Operational	**Functional competence (applied skills, experience)** • Design skills • Project management • Methodological skills • Organizational and time management skills • Information retrieval and presentation skills • Writing, reading and visual communication	**Social competence (behaviour and attitude)** • Decisions in everyday situations • Teamwork and communication skills • Negotiation and Conflict management skills • Ethical skills (sense and knowledge of community values)

3. Concept for supporting the continuous learning for SMEs

3.1 The Digital Factory Academy Concept

Based on the analysis of the operational context of the companies and their needs, a Digital Factory Academy concept was developed. The concept includes the educational perspective (realized with courses), the collaboration modalities and a cyber physical systems (CPS) laboratory, which serves as a testbed in research and development projects. In simple cases, the companies introduce cases related to data visualization, factory information architectures, production control and simulation. These cases can be applied to the project or thesis works done by students and supervised by the universities. On other cases a company can test specific IoT-related technologies in the CPS laboratory. The experts of the university and the engineering students can be involved to the specific research tasks via joint research projects with companies. Fourth possibility is the targeted courses, the aims is to teach to the engineering students and other participants how the business and production processes are digitized in a modern automated factory. The concept provides a common touchpoint for a multitude of education and development related projects and collaboration actions. Furthermore, it unites previously distinct activities under one framework.

The Digital Factory Academy is a part of the digital manufacturing and industrial internet ecosystem. The developed concept is expected to support the continuous learning for the local workforce. The new ecosystem is expected to produce new competencies, support the emergence of new businesses, business networks and spin-offs in the region. The Digital Factory Academy concept is a competence development centre for companies' staff. It offers physical working environment, use of the learning factory in company's development projects and attendance to university courses through the open university.

3.2 Cyber-physical systems (CPS) Laboratory

The digital academy concept utilizes a CPS laboratory, which follows the principles of the Industry 4.0. The CPS laboratory consists of an automatic manufacturing line and various industrial information systems, such as enterprise resource planning (ERP), manufacturing execution system (MES) and product life-cycle management (PLM) system integrated to it. The open source Odoo ERP contains an eCommerce module, which implements the functionality of an online store. The manufacturing line (Figure 1a) consists of a robot assembly station, a machinery unit, a machine vision inspection unit and a high bay rack warehouse. Each unit has a programmable logic controller (PLC), which controls the operation of the unit.

The communication between the units and the MES software is implemented with TCP/IP socket messages. The manufacturing system continuously collects the production and process data and sends it to the cloud service, which can be used for data analysis and visualisation. The system utilizes the gateway architecture pattern in the data collection. In this pattern, a software module called gateway acts as a proxy between the various devices and the cloud service. The gateway collects process data from the PLCs by utilizing OPC UA. The cloud receives the data and stores it to a NoSQL database for further analysis. The data is analysed in real-time using online analysis techniques such as Microsoft Azure Stream Analytics or R programming environment.

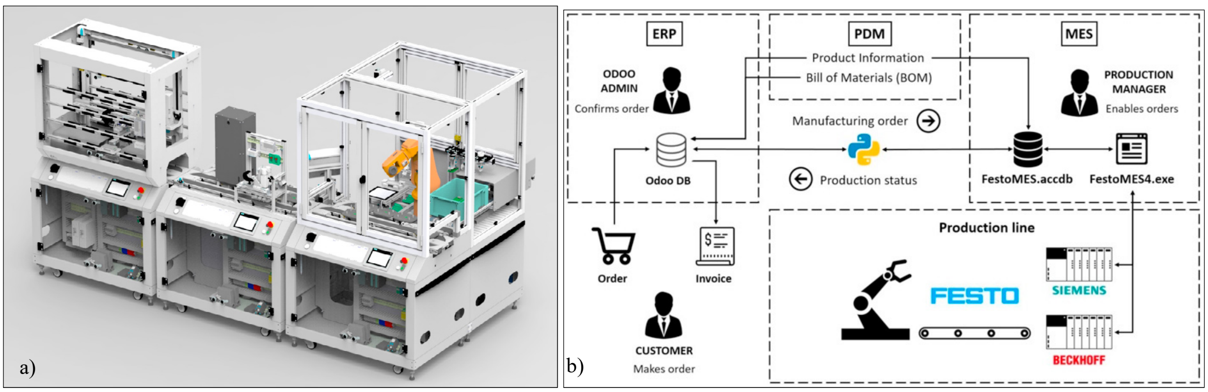

Fig.1. (a) Manufacturing line of the cyber-physical system's laboratory; (b) PDM, ERP and MES integration to the manufacturing line.

Along with the physical environment a digital twin was created, which enables users to simulate the production process with real world data and learn the behaviour of the physical system. The digital twin usually is used for the optimization of the production flow and searching optimal parameters for the production. For example, the machine cycle times of each unit of the physical manufacturing line can be sent to the simulation model via the cloud service. The digital twin has several models, starting with 3D models allowing students to visualise the line and its equipment behaviour. The students have a possibility to alter information models and observe effects produced on the digital twin getting a feedback about the effect brought by information models proposed by students. This is an important viewpoint on a system for a student, because the development of complex cyber-physical systems requires engineer attention at various levels.

3.3. Example of industry-academia collaboration via different project and thesis works within the Digital Factory Academy

The digital Factory Academy groups different activities under one framework. The most common collaboration between educational institutes and local companies a project work or thesis work. The table 4 summarizes typical examples of project and thesis works from 2016-2017. The project and/or thesis work is planned and selected in such manner, that the company will get a solution for a problem from this collaboration.

Table 4. Summary of the typical cases for industry-academia collaboration in education

Types	Typical cases	Descriptions	Competences learned
Project works	Company	Modelling and simulation of robot cell operations	Meta competence, Social competence (team working)
	CPS Laboratory	Development of user interfaces, creation of 3D models of the line	Cognitive competence
Bachelor level theses	Company	Simulation of robot cell operations, Bottleneck analysis of a production line	Meta competence, Functional competence
	CPS Laboratory	Development of Ordering tool, Development of operational dashboards	Meta competence, Functional competence
Master level theses	Company	Evaluation of AM technologies and their maturity in relation to company, Evaluation of demand fluctuations in the case company, Development of polishing process, Automatization of hydraulic tightening cell	Meta competence, Social competence, Functional competence
	CPS Laboratory	Development of role-based dashboards	Cognitive competence, Functional competence

The project works are simple production control or ICT related problem-solving tasks, that require typically teamwork and project management skills e.g. meta competences. The teamwork can be also fostered by students taking different user roles such as a customer, system administrator and production line manager. Functional competence is most strongly developed with respect to design skills, project management and methodological skills. The MSc level theses typically result concrete tools or methods that are applied to the case company immediately. These train especially meta competences, functional and social competences.

4. Conclusions

We have developed the Digital Factory Academy concept for enhanced industry-academia collaboration to support skills development of employees in local companies enabling re-skilling and life-long learning. The Digital Academy concept provides a framework with concrete examples for companies to plan and implement training of current and future employees. The CPS supports both the education and research collaboration between academia and industry. This local implementation of the versatile learning environment supports the problem solving by introducing non-routine, practical and industry relevant problems. Both, the CPS laboratory and its digital twin, allow students and researchers to test and reflect the learning experiences. We expect this to encourage the reconstruction of the meaningful experiences and promoting responsive guidance through mentoring. The CPS laboratory is also sufficiently constructed environment to allow identification of problems and their solutions. Since the line is built inside the academy premises, it supports the boundary crossing between different engineering disciplines. This was evident from the local company requirement collection workshops. The limitations in this concept and approach are related to the location. Finland is a high-cost country producing highly customized high added value products. The Ostro-Bothnia region is suffering from a shortage of BSc and MSc level employees. Higher education institutes and regional companies have long tradition in collaboration. The deepening the collaboration and proposing this systemic approach suits well this particular environment. As a future work, we intend to scale the solution to make it available for other regions of the world.

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