The 5th Conference on Learning Factories 2015

# Industry 4.0 Learning Factory for regional SMEs

Clemens Faller[a]*, Dorothee Feldmüller[a]

*Hochschule Bochum, Höseler Platz 2, 42579 Heiligenhaus, Germany*

* Corresponding author. Tel.: +49-2056-15-8722; fax: +49-2056-15-8799. *E-mail address:*clemens.faller@hs-bochum.de

**Abstract**

The regional SMEs of the lock & key industry around the Campus Velbert/Heiligenhaus need further training in modern technologies enabling Industry 4.0 scenarios and methods to optimize their production themselves. This is delivered by the learning factory with 3 different training setups. Besides this, it is used for the practical teaching of the students and for evaluating research projects.

© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of 5th Conference on Learning Factories (CLF 2015)
*Keywords:* shop floor – top floor integration; automation; Industry 4.0; energy efficiency

## 1. Introduction

A greater flexibility of production systems and processes is necessary to address the increasing complexity of products and supply-chains. This can be realized through IT-integration of the production level with the planning level and further on to customers and suppliers. This will cause efficiently and quickly customized products. This IT integration is realized by cyber-physical-systems, the whole scenario is (in Germany) known as 'Industry 4.0' for some years now [1].

To make today's students and industrial users familiar with the topic and the related challenges, new curricula are necessary. The interdisciplinary and the holistic approach required by the Industry 4.0 scenario are not learned by classical lectures and internships.

Especially small and medium sized enterprises (SMEs) have the difficulty to be highly skilled in applications and technologies of Industry 4.0. This is caused by the fact that those companies usually don't have the manpower to look ahead and beyond their own product and production range to enter new areas and they usually don't have the possibility to invest in emerging technologies as an early adaptor in order not to lose money by focusing on the wrong technologies. Nevertheless those companies need to be trained in demanding technologies to be able to produce efficient enough to survive in the globalized environment.

Therefore regions with traditionally rather small SMEs need the support and knowledge to develop those skills in an effective way. Such a region with many small companies is the region around the smaller cities Velbert and Heiligenhaus. Those two neighbor cities locate the majority of the German lock and key manufacturing companies for buildings and cars. Even some of them are known well, they are all SMEs. They are organized within the association "Schlüsselregion e.V." (key region), which is the industrial network of Velbert / Heiligenhaus region. 150 companies use the club as a communications and meeting place, as short wire to neighboring companies for cooperation projects and a shared commitment to the generation of skilled workers in the region [2]. Together with the Schlüsselregion e.V. the Bochum University of Applied Sciences established a Campus directly in the Velbert/Heiligenhaus region. This campus teaches students in mechatronics and information technology. The students are mostly doing a dual study where they - from the beginning of the study - work in one of those companies located in Velbert or Heiligenhaus.

## 2. The Learning Factory at the Campus Velbert/Heiligenhaus

To enable a practice education of the students on the one hand, and continues training for professionals who are employed by the regional SMEs an Industry 4.0 Learning factory was invented at the campus Velbert/Heiligenhaus (CVH) of the Bochum University of Applied Sciences, where the processes at the shop floor level are integrated to the top floor level and vice-versa to generate a maximum of transparency. Hereby, real-time supply chain information is provided. Improved performance monitoring in a distributed manufacturing scenario and real-time reaction on problems in production processes are supported by this. Also complete information on the product genealogy is collected.
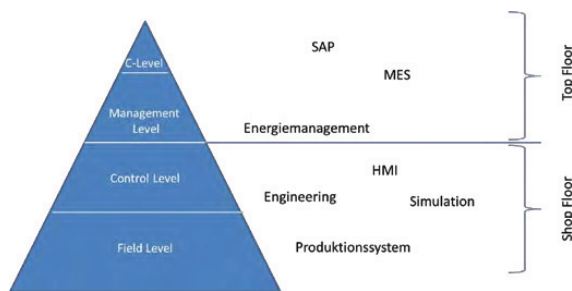


Fig. 1. Learning Factory from Top Floor to Shop Floor

The Learning factory comprises a holistic model of a producing company, from the ERP level – Top Floor – to the Field Level – Shop Floor. SAP as the ERP System is installed. SCADA, MES and Energy Monitoring are IT-Systems from Schneider Electric, also the PLC, HMI and the appropriate Engineering Tools. A Siemens CNC enlarges the range of the used Automation devices in the same way as the Mitsubishi Robot. A simulation and offline programming tool for the robot from Festo is available. A Festo mechatronic and pneumatic transfer system builds the material flow system for the work pieces in collaboration with the robot. The transport belt of the transfer system is driven by a variable speed drive. The components are interacting by the most common industrial communication standards: Modbus, ProfiBus and CANopen as field busses, Modbus-TCP, ProfiNet and OPC (DA & UA) as state of the art Industrial Ethernet systems.

Looking at the dimensions of Learning Factories as defined [3], Product, process, didactic, setting, purpose, the learning factory at the Campus Velbert/Heiligenhaus can be used for many scenarios that can be reproduced, thanks to its holistic approach. The lock and key industry in the region produces mostly mechanical and more and more mechatronic systems. They use mostly the same technologies offered in the learning factory. So physical products and real processes can be trained, analyzed and optimized. The didactic concepts is based on theoretical lectures followed by practical training and integrated workshops where the participants are able to work out their own optimization strategies.

For the students those contents of the learning factory are used in the courses: Automation 1+2, Industrial Management, Mechatronic (Bachelor) and Automation and Supervisory (Master). Since the students are already working for or in projects with by the regional employers the learning factory is used to enlarge the knowledge of the regional companies by default.

But beside the usage in practical aspects of the named lectures, the learning factory is offered to the "Schlüsselregion" network for multipurpose training topics such as "Technical and organizational integration of top floor and shop floor", "Efficient Automation through modern industrial communication technologies" and "Increasing of Energy Efficiency in industrial processes".

The third usage of the learning factory is as a test and evaluation environment for research projects carried out at the Campus Velbert/Heiligenhaus. The research projects of the Automation Laboratory deal mainly with Industry 4.0 and Energy Efficiency questions. The experimental part such as programming, optimization, metering can be done perfectly in a holistic image of a real production facility.

## 3. Technical and organizational integration of top floor and shop floor

One aspect of the learning factory at CVH is to show integration of shop floor and top floor information systems in a production environment.

The status of the production processes at the shop floor level should be integrated to the top floor level to generate a maximum of transparency. Hereby, real-time supply chain information is provided. Improved performance monitoring in a distributed manufacturing scenario and real-time reaction on problems in production processes are supported by this.

The integration of top floor and shop floor is shown by example of integration of SAP system directly with the process control layer. The communication is based on open communication standards as OPC. Possible scenarios are the machine requesting information about the planned variant to be built, controlling this process and reporting completion at the end.
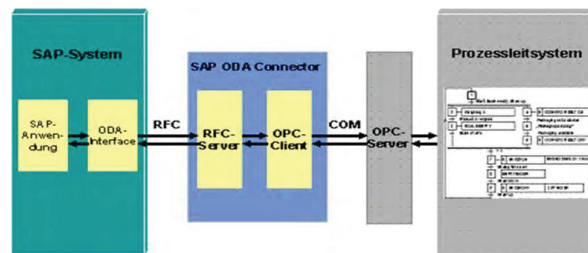


Fig. 2. SAP integration via OPC [4]

The efforts which have to be taken to get this kind of seamless integration between the two different worlds – top-floor and shop-floor – also have to be taken into

consideration. So this learning factory scenario supports a holistic problem-based learning environment.

The purpose of our learning factory for the aspect of integration between shop floor and top floor is mainly for teaching, with opportunities to develop solutions for third parties:

- The participants of seminars will understand the advantages of integration of shop floor to top floor by live demonstrations which may be run through by themselves (Missing or weak integration based on paper exchanged, better integration based on information exchanged automatically).
- The participants of seminars exercise some of the scenarios themselves in a real environment: production orders placed in SAP will trigger real production in a learning factory with physical production environment including a robot.
- The participants of seminars will understand that shop floor and top floor are two different worlds and for integration knowledge of both has to be brought together, which means effort and costs. They will have an overview of the knowledge and the efforts needed. They will be enabled to evaluate scenarios from an economical viewpoint.
- The participants of seminars will have the opportunity to deepen their knowledge in analyzing scenarios and evolving them further by additional indoor work and resp. or a thesis.
- The product considered in our learning factory is a simple physical one with small variation. At this time the product is not focused but the process in a production line which is triggered and monitored via the ERP system SAP.
- The process is realities conform and presents the main part of the automation pyramid in a real scenario: integration of shop floor and top floor including ERP, MES, and PLC.
- Top floor triggers production orders and monitors status and completion. The top floor is physically separated from the shop floor. Some shop floor (office) places are very close to the production line in order to watch the integration effect; other places are in a separate room to simulate remote scenarios often encountered in real life. In such a way, organizational issues concerning collaboration emerge in our learning factory and are part of the demonstration.
- The shop floor production line as already described above represents a real production line.

At a first glance, organizational aspects and economic value added by the integration are taught – corresponding to the first items of purpose named above, especially there are Complete and consistent understanding of information flow in a factory for the complete value chain inside a factory, Collaboration issues, Transparency, Real-time reaction and Improvements for performance monitoring and problem solving in production lines.

At a second glance, when looking at the technical level, the complexity of the integration and economic evaluation of efforts and benefits are taught, such as ERP architecture in total, ERP architecture prepared for interface to production line, ERP customizing issues for interface to production line, OPC standard and architecture, ODA connector for connecting SAP to OPC and its customization.

At the moment the setting is used for on-site learning between the two parts of the shop floor work stations on the one hand and the production line on the other hand which are separated but very close to each other. As described above, it may be also used for demonstrating and exercising a remote relationship between shop floor and top floor.

## 4. Efficient Automation through modern Industrial Communication Technologies

The other important aspect is training and understanding the state of the art automation and industrial information technology related to Industry 4.0 and Cyber Physical Systems. The regional SMEs use mainly rather simple autonomous PLC automated systems. The potential of Interaction between different automated manufacturing and assembly facilities is often not used. The systems are controlling, monitoring and interacting and therefore offer many possibilities to understand the benefit of integrated systems and data.
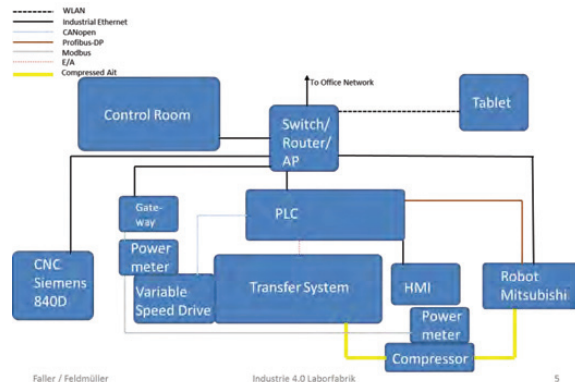


Fig. 3. Automation Architecture

The purpose of our learning factory for the aspect of efficient automation is:

- The participants of seminars will understand the means of modern Automation such as PLCs, CNC and Robot Control.
- The participants have the opportunity to see the differences between the different communications standards and the different strength and weaknesses they have and which technology fits for what application.
- The participants will be able to exercise the usage of all shown technologies.

- In workshops, they can assess the transferability to their production facilities.
- In order to be able to understand and use the benefits of cyber physical systems web technologies are trained generally. In addition the usage of web standards in collaboration with automation systems is shown, such as web services of a PLC or web services for HMI application (e.g. Tablet Apps).
- The mightiness of such technologies especially for real time data analysis and predictive maintenance is shown.



Fig. 4 Energy Dashboards and KPIs

## 5. Increasing of Energy Efficiency in industrial processes

Even for SMEs, Energy Efficiency is one the most important topics today [5]. Many of those companies don't know much about their energy usage and potential to save it. The learning factory is equipped with 8 energy meters in total, connected to the energy monitoring system. During the training, theoretical aspects are shown as well as modern metering technology and monitoring software. In addition, the relation between the energy consumption and the production output can be shown via KPIs to find optimization strategies:

- The participants of seminars will understand the functionality and setup of metering devices and technologies.
- The participants will learn the possibilities of energy monitoring software.
- Energy efficient means for manufacturing and assembly are shown
- The relation of energy efficient devices such as variable speed drives and power quality effects (e.g. harmonics) is shown
- The energy management standard ISO 50001 is explained. In-training workshops enable the participants to elaborate how to implement it in their company.
- The relation between production of work pieces and energy consumption is shown in KPIs. The strategy to define the right suitable KPIs is given in the workshop. The possibility to optimize the KPIs by changing the automation setup is given.

## 6. Summary

As explained before, the regional SMEs of the lock & key industry around the Campus Velbert/Heiligenhaus need further training in modern technologies and methods to optimize their production themselves. This is delivered by the learning factory with 3 different training setups. Besides this, it is used for the practical teaching of the students and for evaluating research projects. Future scenarios may consider the integration of shop floor and top floor via suitable cloud services which might be more promising for SMEs. The efforts which have to be taken to get this kind of seamless integration between the two different worlds – top-floor and shop-floor – also have to be taken into consideration. So this learning factory scenario supports a holistic problem-based learning environment.

## References

[1] Bildstein, A.; Seidelmann, J.: Industrie 4.0-Readiness: Migration zur Industrie 4.0-Fertigung, in: Bauernhansl, T; ten Hompel, M; Vogel-Heuer, B.(Eds.): Industrie 4.0 in Produktion, Automatisierung und Logistik, Springer Vieweg, Wiesbaden 2014, ISBN: 978-3658046811

[2] Schlüsselregion e.V.: http://www.schluesselregion.de/ (11.01.2015)

[3] Tisch, M., et.al.: A systematic approach on developing action-oriented, competency-based Learning Factories, Procedia CIRP 7 (2013), 580-585

[4] Doller, A.: Produktionsplanung mit SAP in der Prozessindustrie, SAP PRESS, ISBN: 978-3836228923

[5] Kring, R: Bewertung der Effizienz von Fertigungsanlagen in: Kreimeier, D.: Ressourceneffiziente Bewertung und Optimierung von Prozessketten, VDMA-Verlag, ISBN: 978-816306276