

Variety Management in Manufacturing. Proceedings of the 47th CIRP Conference on Manufacturing Systems

## Holistic learning factories - A concept to train lean management, resource efficiency as well as management and organization improvement skills

Dieter Kreimeier, Friedrich Morlock, Christopher Prinz\*, Björn Krückhans, Dennis Cüneyt Bakir, Horst Meier

*Ruhr-Universität Bochum, Chair of Production Systems, Universitätsstraße 150, 44801 Bochum, Germany*

\* Corresponding author. Tel.: +49 234 32 26866; fax: +49 234 32 06866. E-mail address: [prinz@lps.rub.de](mailto:prinz@lps.rub.de)

### Abstract

Learning factories have been developed to impart substantial knowledge about improvement process concepts and methods to seminar participants within a real-world manufacturing environment. Thus, it is possible to teach the curriculum's contents in a very practice-oriented manner. The advantages of a real-world manufacturing environment can be used for the academic education of university students as well as for the training of industry participants. More and more companies are convinced of this concept, which is why they are implementing learning factories to qualify their specialists from the shop floor to the management level. The principal aim of learning factories is always to convey their complex view of business processes and impart methods, concepts and which provide for the detection of improvement potentials and the implementation of more efficient processes.

In their early beginnings, learning factories concentrated mainly on the aspects of lean management and process improvement. Due to the rising significance of resource efficiency, however, this issue has become another main aspect in learning factories. This contribution will incorporate the concept of the learning factory at the Chair of Production Systems (LPS). Learning factories cover three topic areas: lean management, resource efficiency as well as management and organization (company co-determination). In spite of the three very different areas, all of these areas are interlinked within the learning factory by the continuous use of one real product, which is produced during the considered processes. This contribution will show how an integration of different areas in one learning factory is possible and how in this way a learning factory is turning into a holistic concept.

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Selection and peer-review under responsibility of the International Scientific Committee of "The 47th CIRP Conference on Manufacturing Systems" in the person of the Conference Chair Professor Hoda ElMaraghy

Keywords: learning factory, lean production, resource efficiency, manufacturing education

### 1. Introduction

Learning factories have been developed to impart substantial knowledge about improvement process concepts and methods to students and industrial seminar participants within a real-world manufacturing environment. The advantages of this specific manufacturing environment can be

used for the academic education of university students as well as for the training of industrial participants. More and more companies are convinced of this concept, which is why they are implementing learning factories to qualify their specialists from the shop floor to the top level. The principal aim of learning factories is to convey a complex view of business processes and impart methods, concepts and tools making it

possible to detect improvement potentials and to implement more efficient processes in the participants' own production environment. The learning factory covers three topic areas: lean management, resource efficiency as well as management and organization (company co-determination). In spite of the three very different areas, all of these areas are interlinked within the learning factory by the continuous use of one real product, which is produced during the considered processes. This contribution will show how an integration of different areas in one learning factory is possible and how in this way a learning factory is turning into a holistic concept. In their early beginnings, learning factories concentrated mainly on the aspects of lean management and process improvement of only one facility.

Due to the globally rising significance of resource efficiency, this issue has become another main aspect in the learning factory of the Ruhr-University of Bochum, which is a member of the European Network of Innovative Learning Factories (NIL).

NIL is a project funded by the German Academic Exchange Service (DAAD) to enhance the mobility between the leading European universities involved in research and operation of Learning Factories.

## 2. Basics of Learning Factories

Manufacturing companies are more and more reliant on well trained employees due to the increasing competition on the world market as well as the rising complexity of production systems. To increase the competences of the employees, knowledge platforms are necessary [1], such as business games. Although these games are increasingly used, observations have shown that the missing real-world manufacturing environment prevents the transfer to their own operational challenges. In addition, it is not sufficiently transported that the employees themselves play a key role in the improvement process [2]. In order to close this gap learning factories are being chosen more and more often as a new knowledge platform and a nearby workplace solution [1]. The transfer of knowledge from trainings to their own companies is favored due to the real production conditions, because process improvements can be practiced risk-free manner and without cost pressure [3].

The trend of learning factories is not only recognized at universities but also at industrial companies (e.g. [1], [2], [4], [5]). The numbers of learning factories in universities and companies are predicted to increase even more in the upcoming years, because there is a greater demand for better forms of learning for the production staff [6].

## 3. Concept of the LPS Learning Factories

The Chair of Production Systems (LPS) established its learning factory (LPS Learning Factory) in 2009 [5]. In its beginnings, the learning factory focused on improvement processes and lean management topics. In the following years, new developments and challenges emerged in production engineering. Due to the increasing costs for resources like material and energy as well as the social change to an

environmentally friendly atmosphere, the topic resource efficiency has become more and more important. Another area which is equally relevant for companies is the management and organization of work as well as the co-determination. The economy crisis a few years ago has shown that German industry, with its unique work council system, has not taken as much damage as other countries.

These new challenges require the consideration of all mentioned topics for the training of industry participants and students. As describes in chapter 2, learning factories are a practice-oriented way to train industry participants and students. The object of the LPS is to consider even new topics in a learning factory. In order to realize this aim in an easy and cost-efficient way, the infrastructure of one learning factory combined with one product is considered with regard to the three topics of lean management, resource efficiency as well as management and organization.



Fig. 1: LPS learning factory

### 3.1 Learning Factory - Process Improvement (LPI)

The main obstacle to the implementation of lean production systems is the refusal by employees. This is often due to a lack of knowledge about lean production and inadequate training [7]. To close this gap, a rapid practical application of the learned knowledge is necessary [8]. Since employees represent the key element in corporate culture, an additional enhancement of the problem solving and improvement culture within companies is required [9]. Because of their persuasive power, practical and action-oriented approaches, such as lean business games, are established in order to train employees at all levels [10].

The LPS Learning Factory for process improvement conveys the topics of lean management and industrial engineering in a practical and action-oriented way by trainings for students as well as for industry participants. As an introduction to the topic, an assembly simulation is performed by using LEGO® cars. Without previous training, teams of two members assemble cars in several rounds of simulation, in which the participants intuitively apply adequate continuous process improving techniques such as visualization, standardization and the division of labor. Only afterwards are the used methods named explicitly and theoretical knowledge added. From a didactic point of view, this "playful" approach has the advantage of overcoming lower inhibitions to access the topic.

Due to the integrated learning environment of the learning factory the 5S method, which is often implemented first in companies, can be taught in the second learning unit at existing, real work stations. This method is very easy to use and has the possibility to be linked to existing content already available. These real work stations (e.g. CNC miller etc.) are transferred into different initial situations (5S levels of maturity). In addition to the 5S method, topics and techniques such as audits, Maturity, waste, Waste walk and Chalk circle are also taught in the learning units.

To get an overview of the interlinking of workstations with shared material and information flows, the value stream method is taught with the help of the manufacturing of a real product (bottle cap). In this case there are mechanically produced parts (on site) as well as purchased parts available. The components are assembled and prepared in a packing station for delivery. The participants can increase their theoretical knowledge by applying an actual value stream.

Subsequently, a target value stream is developed by small groups under the guidance of the moderator. Lean methods such as Supermarket, Kanban, Pull and Just-in-time (JIT) / Just-in-sequence (JIS) are used as well as industrial engineering tools for instance line balancing and job optimization. The changes developed in the target value stream like aligning to the customers need are then put into practice. An additional simulation round shows that the methods lead to significant improvements. This can be proved by key performance indicators like processing time and stocks.

The final learning unit “process improvement” contains an overall summary. A workflow from customer to distribution with suppliers and indirect departments is simulated – again it is initially an actual flow revealing significant potential for improvement. The participants then have to develop a target value stream when applying the learned methods and tools. Finally, a last simulation shows the substantial improvements, which can again be proven by key performance indicators.

Altogether, the concept of multi-level teaching of the LPS learning factory provides a playful access to the topic of lean management, where theoretical content is immediately is converted into practice by using various methods of the lean toolbox (see Fig. 2).

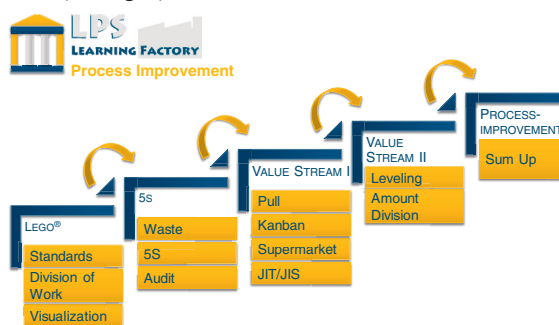


Fig. 2: learning curriculum of the LPS Learning Factory for process improvement

### 3.2 Learning Factory – Resource Efficiency (LRE)

Due to ecological reasons, especially for the manufacturing industry, it becomes more important to focus on resource (energy and material) efficiency. Not merely the political circumstances but rather the increasing resource prizes and the raising competition on an international level qualify resource efficiency as a future key factor of competition [11]. Instead of just focusing on the three typical indicators of time, costs and quality, a more extensive focus on the issues of energy and material efficiency, thus reducing CO<sub>2</sub>-emissions, can be profitable for the manufacturing industry [12]. Meanwhile there is a variety of consultants and instructors, who concentrate on resource efficiency on the one hand while offering adequate learning factories only rarely.

The developed didactic concept of sensitization for the design of Energy and -Resource-efficient production processes, as presented in the following, is an essential basic element of the learning factory for resource efficiency at the Ruhr-University of Bochum.

Within the LRE, four strategic concepts are addressed, for participants from the shop floor level up to the top floor level. A structured model for the identification and assessment of process-inherent potentials, as shown in Fig 3, is the basis which enables participants to transfer learned concepts to their own company and processes.

The aim is to understand the information path from the signal to the finished KPI to track and optimize production processes using the measured data.

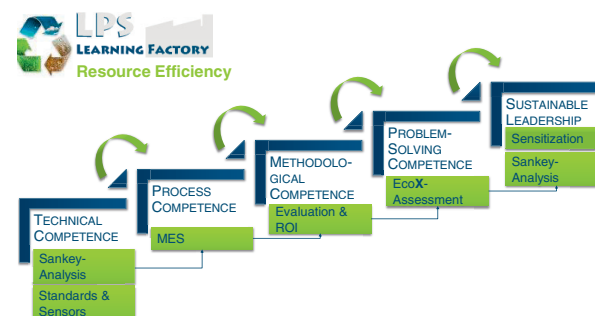


Fig. 3: Concept of the LRE

At the beginning of the manufacturing, the participants have to talk to the customer of the component which is to be produced. During the dialog, the customer highlights that a stamp box should be manufactured in a particularly resource efficient way.

The focused stamp box is didactically developed in order to make it possible to manufacture the product in the focus of resource efficiency on the available machines in the learning factory up to distribution.

As a second step, the participants have to analyze the production material and information flows.

During the stage of analysis, the value stream technique and the material stream mapping are used.

Data analysis is conducted in step 3 by using the installed measurement sensors. All in- and output parameters are

metered in a cyclical way in order to find the main consumers and to understand the processes. Based on this pool of information, manufacturing processes can be rated. During the analysis phase various software tools make it possible to measure in different granularities. The measuring instruments provide a direct evaluation every 100 ms. The valid distribution of sensors and allocation of measuring points is an essential step to create a survey space and to build up key performance indicators (KPI).

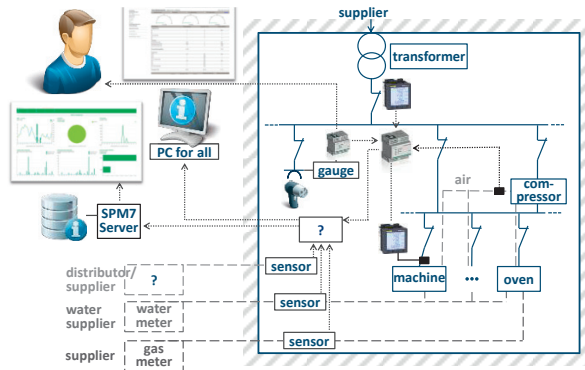


Fig. 4: Workshop - data acquisition

Therefore, the workshop teaches how to acquire essential data (Fig 4) and how to get well-based KPIs and optimization measures provide all relevant information for the following step of a resource-driven Sankey analysis, identifying resource-efficiency *HotSpots* within the addressed processes [13].

Additionally, all values are saved into a Manufacturing Execution System (MES) and can be accessed for evaluation and the planning of further orders.

The discovered capability for optimization is prioritized in action plans, implemented and investments are monetarily rated.

### 3.3 Learning Factory - Management and Organisation (LMO)

Beside the two areas, process improvement (lean management) and resource efficiency, there is one other area exists at the LPS Learning Factory: management and organization. This area concentrates on the topics of co-determination and change management. While the focus of the LRE and the LPO is set on processes, the main object of this area is the human factor. Germany has a unique system of co-determination not only on the level of trade unions but also on the company level. The employee's representatives on company level are bound to a special German law. German engineering studies are rather technically concentrated and thus management leaders are not familiar with this topic, which may cause problems in the company later on. This is the reason why the LPS has developed an interdisciplinary seminar in with cooperation the Faculty of Social Sciences and the Office of Cooperation Ruhr-University of Bochum - Industrial Metal Union (IG Metall). This cooperation includes the development of new learning units for management and

organization topics. These units are, of course, based on the very sufficient and advanced learning for process improvement. The main focus of the LMO is set on the human factor within the working environment of a factory. At first the participants are introduced to the pull-/push strategies for material flow control and the procedure of activity structure analysis. Thus they are lead to the topics of change and analysis of human resource. The next seminar stresses the subject of change management where the participants have to optimize manufacturing and business process in consideration of employee integration. Especially a well-organized and early comprehension of employees in the change processes shows a better acceptance of the organizational change [14]. The final seminar focusses on the unique laws in Germany, which allow work councils to engage (e.g. veto) in dismissals, reorganization, etc. The participants experience the responsibilities of both sides (management and work councils) within a real-world manufacturing environment.



Fig. 5: Teaching concept of the LMO

## 4. Outlook

This paper presents the motivation and importance for learning factories in order to train and sensitize employees or students in a practice-orientated way. A learning factory no doubt requires a lot of equipment and resources but the LPS learning factory shows that one learning factory can cover three important challenges like process improvement (or lean), resource efficiency and management and organization improvement skills in one learning factory. The fact that the same area and resources as well as a real product is used in a real-world manufacturing environment presents the huge advantage of the LPS learning factory.

## Acknowledgement

Parts of this article have been elaborated during the research and development project rebas "resource efficient development and optimized operations of filling-facilities within the food industry through development of a novel simulation software" within the Ziel2-Call "Ressource.NRW", which is promoted by the German State Agency of Nature, Environment and Consumer Protection and is supervised by the Efficiency Agency of North-Rhine Westphalia.

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