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Integration of Industrie 4.0 in Lean Manufacturing Learning Factories

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Abstract

Industrie 4.0 is referred to as an umbrella term for various digital concepts e.g. IoT, CPS, Big Data, Data Analytics, Digital Twin, Digital Shadow, HRC, etc. Said concepts promise new potentials for production planning and steering (PPS) optimization. In particular, data availability is an enabler for an efficiency increase in PPS. Managers of lean manufacturing systems question how to integrate these new possibilities into the existing philosophy and optimization projects. It is currently uncertain whether Industrie 4.0 approaches replace or revive lean manufacturing. Within the *iwb's* learning factory, we illustrate lean and Industrie 4.0 as complementary approaches by postulating five theories concerning their interaction. This paper presents the introduction of Industrie 4.0 into the program of the learning factory by proposing two integrated teaching. The concept was successfully implemented within the *iwb's* learning factory.

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1. Introduction

"Industrie 4.0" (I.4.0) and the related involvement of information and communication technologies in production is an impulse for manufacturing companies to think about the adaptation and change of their current production systems [2]. Existing learning factories, such as the Learning Factory for Lean Production (LSP) of the Institute of Machine Tools and Industrial Management (*iwb*) at the Technical University of Munich, need to integrate the emerging

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digitization trends into the training concept, in order to keep their central role in promoting process orientation in manufacturing systems (cf. e.g. [3–6]). Hence, the compatibility of the lean philosophy and the new digital possibilities of I.4.0 need to be investigated. In this contribution, the main principles of lean production are discussed in the context of increasing digitization. Based on this, five theories are derived and form the requirements for the integration of I.4.0 into the LSP through so-called *"I.4.0-challenges"*. For this purpose, a procedure for the preparation of I.4.0-challenges is presented, which supports the concept of problem-based-learning (cf. e.g. [7]) of the LSP. Finally, the implementation of the challenges in the LSP is described. This paper aims on contributing a promising approach to enhance the existing training concepts in lean learning factories in order to meet the evolving new requirements in the context of Industrie 4.0.

2. The LSP Learning Factory for Lean Production

The aim of the *iwb's* Learning Factory for Lean Production (LSP) is to teach the principles and the methods of lean production in a sustainable way. Therefore, the *iwb's* learning factory provides a reality-conform production environment for the assembly of planetary gearboxes. Consisting of seven fully flexible assembly tables, two rack storage systems, and a comprehensive set of equipment, the LSP represents a flexible, modular assembly system, which supports the realization of different production structures as well as different material supply strategies. It is comparable to other learning factories, however, it focuses on flexibility (all equipment is transportable and quick-adjustable) and is unbiased as to the result.

The didactic concept of the LSP is based on three main steps: (1) Theoretical method training, (2) simulation games, and (3) the transfer into the real production environment of the learning factory. The methodology training is embedded in the philosophy of lean manufacturing and starts with the mediation of the lean production's background and the Toyota production system. Subsequently, different methods of lean production are trained. In order to illustrate the theoretical content and to make it perceptible, selected simulation games (2) are carried out. For example, using a slightly modified version of the Lean Enterprise Institute's Airplane Game shows the difference between push and pull steering. The transfer (3) begins with an assembly run with a high level of waste within the gearbox assembly's value stream. From this starting point, the participants successively try to eliminate the existing waste by changing the production setting. The improvement's results are measured during a final assembly run using key indicators as e.g. delivery reliability. Depending on the available time, different numbers of assembly runs are completed. In this way, the participants directly notice and experience the improvements, which arise through application of the taught methods.

3. Lean and Industrie 4.0

3.1. Principles of Lean Management

In literature, numerous approaches explain lean management by different "principles", "guidelines", or "rules". Based on the values of the Toyota Production System, Womack & Jones [8] derive five general principles: (a) value, (b) value stream, (c) flow, (d) pull, (e) perfection. These can be supplemented by the principle (f) Respect for People, which the founders of the Toyota Way regard as a fundamental basis for a trusting cooperation of all employees. In order to create a later comparability with the developments in the I.4.0, the following section briefly explains these basic principles of lean production.

(a) Value: according to Womack & Jones [8], the definition of value must always be made from the customer's point of view. All customer requirements – this means not only of the recipient of the final product, but also the person who carries out the subsequent manufacturing activity [9] – must be satisfied.
(b) Value Stream: the value stream comprises all steps that are necessary for a product's creation – from customer order to delivery [10]. The identification of the value stream significantly increases the understanding of the process and hence, helps to disclose problems that previously were undetected [11].
(c) Flow: the flow principle fundamentally fulfills the Toyota Production System's guiding principle of customer orientation by shortening the time from order entry to delivery with clear value stream based production layout.