Learning Factory for Digitization of Enterprises

Jens Mathis Rieckmann[a] and Thomas Knothe[a]

[a] *Fraunhofer Institute for Production Systems and Design Technology, Pascalstraße 8-9, 10587, Berlin, Germany*

Abstract

The fourth industrial revolution stands for higher flexibility and productivity of companies. This requires intelligent and interconnected production systems with a well-trained staff. This article describes how the necessary qualification processes can be performed. A high degree of individualized products requires more digitized information (e.g. via IoT, sensors, RFIDs) and a flexible form of work. Today's changes in enterprises are focusing on upgrading the technical equipment. Dealing with changing the mental setting of the staff, enabling employees for digitalization and learning to cooperate in a smoother way (social learning) play an important role. Sensitization regarding necessary changes, decentralized decision-making and cooperating are the main goals for a training. Nevertheless, company's employees also need new technical skills to prepare the enterprise for higher levels of digitization. Learning factories include a stepwise evaluation and transformation of a model factory by the participants themselves. Performing group work sessions, participants have to agree on the future organizational structures, regardless of their function or role as worker, manager or administrative employee. In the upper level of production system design, a high level of digitization is the aim and most of the information flow should be automatically handled. In order to give participants a feeling for introducing extended IT support and using standard interfaces, they have to overcome some technological gaps. An example of a training factory is presented, which is focusing on the transformation of these production systems with different production steps.

Keywords 1

Learning factory, training, employee education, Industry 4.0, smart manufacturing, transformation

1. Introduction

The ongoing globalization and the changing demand of customers accompany the fourth industrial revolution. Customer individual products and shorter product life cycles cause challenges. Germany's Industry 4.0 offers a solution to handle these new challenges. Politically, economically and especially technical drivers are forcing companies to build up on their implemented holistic production systems and to do the next step towards smart manufacturing [1, 2]. Decentralization, real-time ability and different supporting technologies play a central role moving towards Industry 4.0.

The goal regarding autonomous communication among components, production systems, transport media and further production capabilities, as well as the integration of actors of the value chain (including customers and suppliers) causes big challenges for companies (e.g. unclear economic benefit [3] and the changing need for employee qualification [4]). Certainly, the qualifications, but also the sensitization of employees on different company levels, in order to make the transformation successful, is considered as very complex [4]. A main focus of the teaching application is on a proper degree of complexity and the methodical approach [5]. That means not only the real enterprise operations need to be optimized but also the qualifying measures have a high priority to get optimized.

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EMAIL: mathis.rieckmann@ipk.fraunhofer.de
ORCID: 0000-0001-7150-196X

An efficient way of qualification approach is the use of serious games [6]. The focus of serious games is on the simulation of the real enterprises and enterprise environment but at the same time on the reduction of complexity and on keeping the training equipment as simple and mobile as possible. The scope is kept narrow in order to control the complexity and focus on prioritized topics and the most important contents. Clear and structured rules are provided to the participants in order to reach the aimed qualification [7]. Regarding complex learning content and topics, especially technical foci, serious games are limited. Some specific technical aspects can be part of the application, but the holistic company environment and realistic implemented technical tools might cause a conflict with the idea of the reduction of the reality of a serious game and the mobile training equipment. In contrast, training factories are offering, based on a fixed location, an enlarged and realistic training environment [7, 8]. In this article, an example of a training factory is presented focusing on the transformation of production systems with several production steps. The use case will demonstrate the method and content of a training factory application. Furthermore, the future extension possibilities of the training factory towards administrative tasks and SCM (supply chain management) is discussed. The application is based on the experience of Fraunhofer IPK (Fraunhofer Institute for Production Systems and Design Technology, Berlin, Germany). Fraunhofer IPK's main business is to develop new technical solutions for smart and interconnected enterprises, but increasingly also the upskilling of staff is part of the services.

The article is dived into four sections. It starts with the challenges of the fourth industrial revolution including of the challenges for employees. The second section deals with the qualification requirements of smart manufacturing, and the third part presents a use case of a training factory to overcome the challenges and to offer qualified training activities. Finally, limitations and further developments are discussed.

2. Challenges of industrial revolution

Customized products and short product life cycles along with strong competition are challenges for enterprises acting locally and globally. In order to face these challenges higher flexibility and productivity are needed to be competitive. Industry 4.0 – the fourth industrial revolution – creates the framework to handle this challenge. Efficiency of energy consumption and other resources but also the demographic change are the basic topics enterprises need to deal with [9]. The transformation – especially the digitalization – has a strong impact on human resources on different levels.

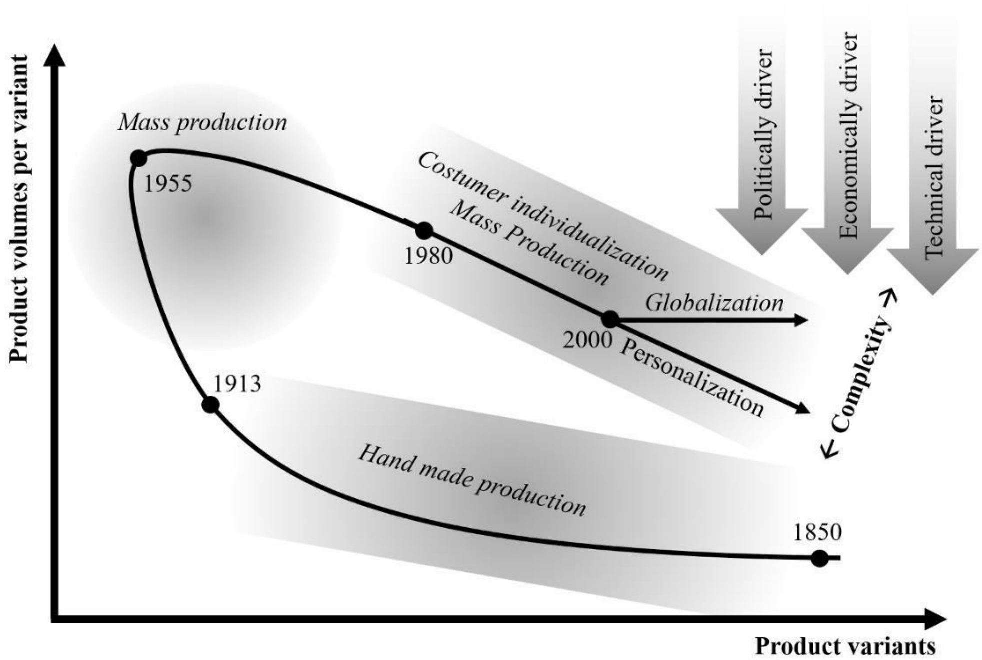

Figure 1: Market evolution view and direction (based on [11])

Technology to realize the digitalization and the vertical and horizontal integration are supporter to face the three main challenges. This counts in particular also for the manufacturing industry [10]. The challenges point in the same direction: higher product variants and smaller volumes per product (see figure 1). Customer-oriented or personalized products increases process variations at the same time it decreases the advantage of identical procedures, thus more specific processes are necessary. The globalization cause the same effect and generate more complexity [11].

The increasing complexity leads to more complex information and production processes, including machines, systems as well as supporting software. Several sets of data need to be rearranged, relocated, formatted and/ or adjusted. Many of these tasks need a lot of manual work or at least preparation by humans. Although a continuous and integrated end-to-end engineering exists, overlapping product life cycles increase the complexity. The shorter becoming product life cycle and decreasing time of products on the market does not decrease the request for ongoing innovations. Novel and innovative production are still very important to stay competitive. Acting on volatile markets also requires interdisciplinary and internationally networks to manage complex value chains. Every restructured and enlarged cross-border business activity requires reorganization or changes of existing processes to adopt them to different conditions [9, 12, 13]. That also means that requirements regarding qualification and skills of employees need to be adopted [14].

The three challenges outlined above create the need to handle the increased and more complex information and material flows. Intelligent systems, which need to be developed and implemented to drive the transformation towards smart manufacturing, support the agent-based production control by using AI (artificial intelligence). The stocks of material and resources are automatically updated (mostly in real-time) and production orders are assigned to suitable machines according to the current situation. The production controller itself does not need to take any decision. The system requires an increasing connection between production and logistics, whereby assistance systems also control the internal and external material flow. This displays new requirements of operational procedures at the production control. Future tasks are related to interdisciplinary development of logics regarding interaction and processing rules. IT (information technology) experts as technical key persons are reference points of different employee groups in order to develop the supporting systems. Employees whose work involve the exchange with the IT experts need different skills in order to match the changing job profile [14, 15].

3. Qualification requirements of a smart factory

Based on the idea to have more flexibility, a higher productivity and a faster reaction time regarding market changes and customer demands, the information flow plays an important role. It requires suitable systems to ensure an effective stream of information but also specific qualification of the employees are needed. Employees on all levels (e.g. assembly worker, line manager but also middle and high management) need skills in order to provide the right information at the right time for order-individually processes. Specific information need to be connected, e.g. tracking of orders and locating errors through the complete value-creation process requires a continuous integrated end-to-end process from the product configuration via the shop floor to the final outgoing of goods. Decision-supporting systems on shop floor level, AI assistant support or BI (business intelligence) build up on the fed data but even more how data sources are connected. The integration of PDM (product data management), PLM (product lifecycle management) and ERP (enterprise resource planning) systems support the process but at the end, it requires the setting and configuration of humans in order to let the systems work efficiently. The competency of the employees regarding processes, intercommunication and interoperability are essential [14, 16].

One step before, in order to introduce new systems a knowledge base is necessary, at least an overview regarding IT support systems and AI solutions. This builds the framework to evaluate and get use of the potential of the system, to find and record requirements, to identify options, and finally to configure the value added components and do the first steps regarding an effective implementation [14, 16].

From a methodically view, knowledge regarding information model and process thinking, and some elementally skills regarding modeling are needed. For interdisciplinary connection along the supply-and value creation chain, skills regarding openness and communication, and a broad understanding of existing enterprise division are necessary.

Last but not least, the overall sensibility regarding new technologies is one of the most important topics in order to finish a successful implementation using different methods, systems and physical elements, and become a smart enterprise [14, 16]. Table 1 summarizes comprehensive qualification requirements.

Table 1
Comprehensive qualification requirements [16]

	Technical/ functional	Methodical	Social
Employees from all operating areas	Comprehension and design of multicultural interdependencies using big data	Process orientation	Interdisciplinary collaboration
	Basics of IT system support and AI assistance systems (incl. potentials and requirements)	Basics of information modelling and transfer	Openness
		Basics of integrated production systems und their methods (incl. CIP)	Communication skills along the value chain

There are also employee group-specific requirements regarding the technical/ functional, methodical and social qualifications. The enterprise areas of a manufacturing enterprise are used to display an example of specific qualification requirements (see Table 2).

Table 2
Qualification requirements clustered by operating areas [16]

	Technical/ functional	Methodical	Social
Top management	Identify new trends and benefits of digitization	Define digitization strategies	Willingness to collaborate
		Support transformation	Promotion and controlling of decentralized to autonomous work units
Administration	Structuring and multiple use of data	Streamlining of supporting processes	Internal and external service mentality
Product development	Controlling of interoperable systems	Multi-criteria simulation of product characteristics	Systematic collaboration with competencies throughout the product life cycle
	Design and development of digital product twins	Ability to innovate throughout the product life cycle	Balancing of processes for product innovation and optimization
Industrial engineering (planning)	Factory planning with uncertain input data	Simulation of production systems	Coordination capacity
	Integrated use of plug and produce concepts	Analytical capabilities	Assessment capacity
		Apply innovaton methods	Integration capacity
Production management and logistics	Self-organization of intralogistics	Analytical methods for high-variant processes	Communication with less hierarchy
	Integration of supply chain and production control		Progressive error culture
Production and maintenance	Robot technology	Analytical skills	Assumption of responsibilities

4. Learning factory approach

A learning session at a learning factory needs to select the content from the three central sections (technical/ functional, methodical and social). In order to provide an effective training it is useful to select focus topics to form modules and to combine them step-by-step [17]. The methodic mix of theoretical input, practical examples (learning by watching) and practical exercises (learning by doing) in combination with social interaction in small groups is effective and promises success (see Figure 2). The group work sessions with small group of participants (four to six persons) have different topics. The groups rotate so that every participant takes part in every exercise session. The group work results are verified by real application cases. The flexible training allows to offer additional theoretical sessions in order clarify open questions with theory input.

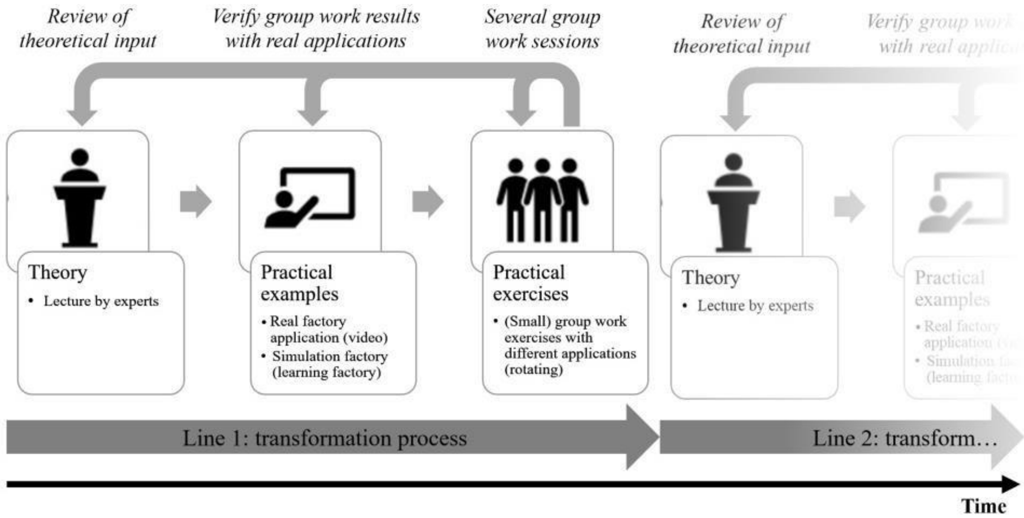

Figure 2: Approach for training factory with focus transformation (methodology)

This typical approach for learning factories generates motivation and allows that participants learning through play, based on the positive atmosphere. The use case of Fraunhofer IPK's learning factory follows a transformation process (see Figure 3). Focus is mainly on understanding and identifying requirements and effects of technical supporting equipment, and fostering the interdisciplinary teamwork.

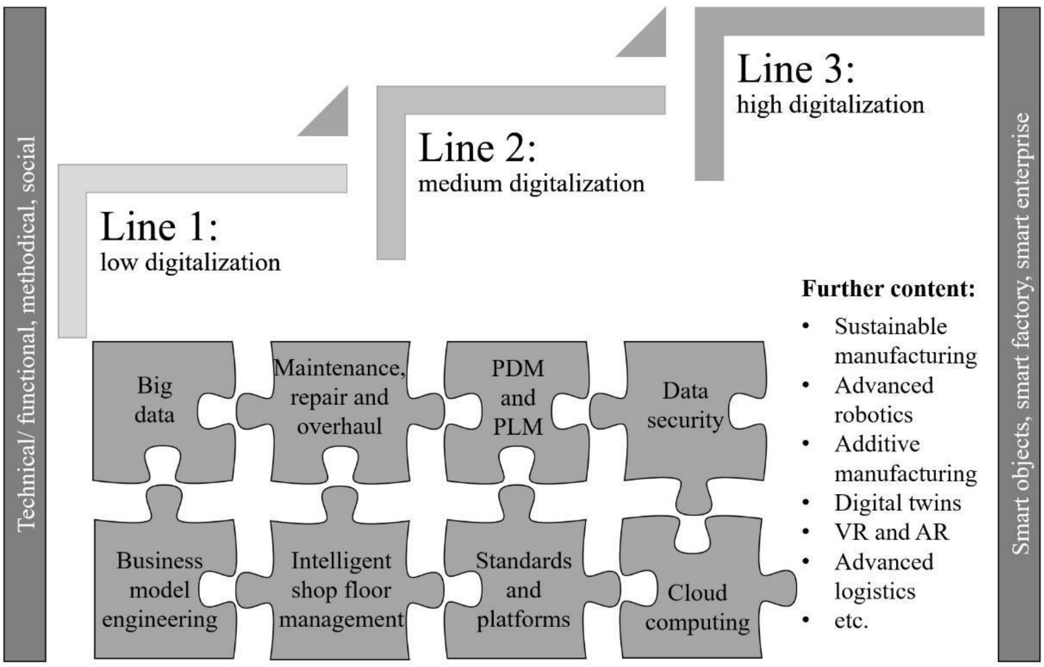

Figure 3: Approach for training factory with focus transformation (content)

Fraunhofer IPK implements a learning factory that is based on three assembly lines to produce a product in different variants. The assembly lines have different technology levels. The first one presents a case with a very low level of digitalization and low degree of automation; most of the work is done manually. The participants are working in teams to develop solutions to bring the assembly line to an advanced production level [18]. The developed solutions are partly implemented and evaluated. The third example presents an almost full-digitalized and full-automated application. On the way to the best-practice example, all essential sections of the transformation process are addressed [14]:

- Technical/ functional: e.g. implementation of RFID (radio-frequency identification) technology in order to record incoming material/ resources and outgoing goods; implementation of advanced robot technology to increase the degree of automation
- Methodical: e.g. implementation of CIP (continuous improvement process) method as an element of an integrated production system; implementation of process-oriented analytics
- Social: e.g. sensitization and support of willingness and openness to perform changes; introduction and use of interdisciplinary communication and collaboration

5. Conclusion and further development

The advanced approach of the learning factory fulfills the industrial demand of employees' qualification in order to push the transformation process. Most enterprises have experienced that the transformation process towards smart manufacturing is long and consumes numerous resources. The awareness of learning factories is still not a fixed element on the path to become a smart enterprise. Some enterprise fall back into their old routine and try to drive the transformation process with a tool-orientated investment policy instead of paying attention to methodical and social qualification elements.

All levels of employees need to be involved to perform a successful transformation process in a company (i.a. assembly worker, line manager, middle and high management). The demonstrated use case from Fraunhofer IPK focuses mainly on the manufacturing process at the shop floor. A future extension of the training factory towards administrative tasks and SCM is planned to ensure the quality and to increase the acceptance. This will be an additional value because the entire enterprise environment displayed in the learning factory: qualification on all levels and for most sections that are important for the transformation is provided.

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