

The 5th Conference on Learning Factories 2015

Learning Factories for research, education, and training

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Abstract

In the last decade, numerous learning factories for education, training, and research have been built up in industry and academia. In recent years learning factory initiatives were elevated from a local to a European and then to a worldwide level. In 2014 the CIRP Collaborative Working Group (CWG) on Learning Factories enables a lively exchange on the topic “Learning Factories for future oriented research and education in manufacturing”. In this paper results of discussions inside the CWG are presented. First, what is meant by the term Learning Factory is outlined. Second, based on the definition a description model (morphology) for learning factories is presented. The morphology covers the most relevant characteristics and features of learning factories in seven dimensions. Third, following the morphology the actual variance of learning factory manifestations is shown in six learning factory application scenarios from industrial training over education to research. Finally, future prospects of the learning factory concept are presented.

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Peer-review under responsibility of the organizing committee of 5th Conference on Learning Factories (CLF 2015)

Keywords: learning factory; morphology; education; vocational training; competency development

1. Motivation

Industry’s urgent challenges are ranging from the integration of new technologies (currently in particular the transition to ad hoc networked, real-time, adaptive, decentralized and self-optimizing Cyber-Physical-Production Systems) over demographic change to volatile business environments in general. In order to survive companies need to be able to quickly adapt to new market conditions. This ability of the company is highly dependent on the ability of employees on all hierarchy levels to act self-organized in unknown situations and to find creative solutions [1,2]. For developing employees’ competencies for manufacturing environments, traditional teaching methods show limited effects [3]. Therefore, new learning approaches are needed

- that allow training in realistic manufacturing environments

- that modernize the learning process and bring it closer to the industrial practice
- that leverage industrial practice through the adoption of new manufacturing knowledge and technology
- that boost innovation in manufacturing by improving capabilities of young engineers, e.g. problem solving capability, creativity or systems thinking capability – talent based innovation is the number one driver of manufacturing competitiveness [4].

Universities and training facilities are confronted with the challenge to identify future job profiles and correlated competence requirements and they have to adapt and enhance their education concepts. Especially, innovative learning environments have to be able to react on above mentioned challenges. Industry now demands interdisciplinary training, which underlines the already proven education and training in learning factories.

2. History of learning factories

In 1994, the National Science Foundation (NSF) in USA awarded a consortium led by Penn State University a grant to develop a “learning factory”. This is when the term was first coined and patented. It referred to interdisciplinary hands-on senior engineering design projects with strong links and interactions with industry. A college-wide infrastructure and a 2000 square meters facility equipped with machines, materials and tools was established and utilized to support hundreds of industry-sponsored design projects since 1995. This program was recognized nationally and received the National Academy of Engineering’s Gordon Prize for Innovation in Engineering Education in 2006. This early model of learning factories emphasizes the hands-on experience gained by applying knowledge learned at the culmination of engineering education to solve real problems in industry and design/re-design products to satisfy identified needs [5–7].

More recently the use of learning factories has increased, particularly in Europe, and has taken many forms of facilities varying in size and sophistication aiming to enhance the learning experience of trainees in one or more areas of knowledge. In the last years numerous learning factories have been built up [8,9]. The Institute of Production Management, Technology and Machine Tools (TU Darmstadt) had one of the early learning factory implementations of this new wave in 2007. Two real products are produced in a complete value stream from raw materials to the shipped products. Also several other learning factories with other foci and physical manifestations were built up in this time. The broad variety of learning factories is shown in section 5 of this paper.

With the establishment of the Initiative on European Learning Factories in 2011 at the “1st Conference on Learning Factories” in Darmstadt the topic “learning factory” took a next step to joint collaboration throughout Europe. In 2014, additionally a CIRP Collaborative Working Group on learning factories was initiated in order to establish a joint

understanding of relevant terms surrounding action-oriented learning and learning factories, to gather knowledge of the global state-of-the-art, and to generate input for further research programs and collaboration models.

3. Terminology and definition of learning factories

In order to find a common understanding of the term “learning factory”, inside the CIRP Collaborative Working Group on learning factories various existing definitions of “learning factories” and “teaching factories” were collected, analyzed, and compared in order to extract dominant key features in all definitions, see also Fig. 2. Numerous discussions inside the CIRP community lead to joint understanding of learning factories in the narrow and learning factories in the broader sense.

The label “learning factory” with the composition of the two words “learning” and “factory” is to be used for systems that address both parts of the term – it should include elements of learning or teaching as well as a production environment [8]. The word “learning” in the term, as opposed to teaching, emphasizes the importance of experiential learning where research has shown that learning by doing leads to greater retention and application possibilities than traditional methods such as lectures, see e.g. [3].

Learning factories provide a reality-conform production environment as a learning environment where only minor abstractions are possible. This means processes and technologies inside the learning factory are based on real industrial sites. In learning factories not only single workplaces or machines, but changeable multilink value added chains are available, which enable a direct approach to different phases of the product creation process [9–11]. Trainees can discover and test approaches or conduct experiments in this environment on technological and organizational industry-related issues [12–14].

The main goals of learning factories are either

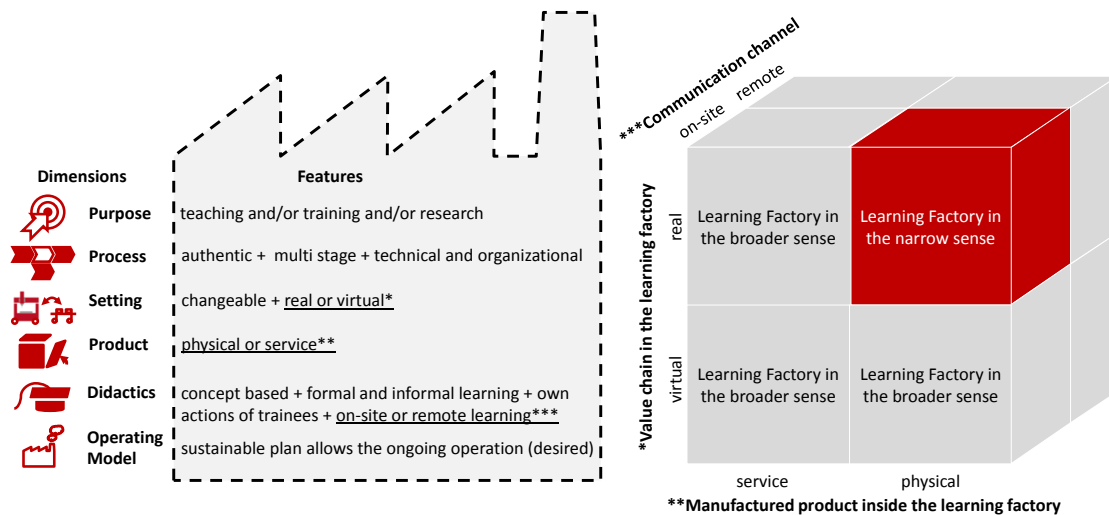


Fig. 1: Key features of learning factories and distinction between learning factories in the narrow (red cube) and in the broader sense (all grey fields)

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