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# Learning Factories

Concepts, Guidelines,  
Best-Practice Examples



station to station. This improvement showed that *SmartFactory<sup>KL</sup>*'s approach was not only valid for one production line, but for various lines—or even various sites, thanks to the now decoupled logistics. Again, 18 partners participated in the consortium.

2018—Together with 19 partners in the consortium, *SmartFactory<sup>KL</sup>* is currently working on topics such as vertical integration (implementation of Edge Devices to prepare for Cloud Computing), the use of 5G applications in an industrial setting and an advanced modular safety concept.

## 11.29 Best Practice Example 29: Smart Mini-Factory at IEA, Free University of Bolzano, Italy

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Name of learning factory: **Smart Mini Factory – Laboratory for Industry 4.0**  
 Operator: **Ind. Eng. and Autom. (IEA) – Free University of Bolzano (Italy)**  
 Year of inauguration: **2012 Lean Mini Factory and 2017 Smart Mini Factory**  
 Floor Space in learning factory: **250 sqm**  
 Manufacture product(s): **Pneumatic Cylinder, Pneumatic Impact Wrench**  
 Main topics / learning content: **Smart Manufacturing Systems, Automation**

Extract from the morphology

2.1	main purpose	education		training		research		
2.2	secondary purpose	test environment / pilot environment		industrial production	innovation transfer		public image	
3.1	product life cycle	product planning	product development	prototyping		manufacturing assembly logistics	service	recycling
3.2	factory life cycle	investment planning	factory concept	process planning	ramp-up		main-tenance	recycling
3.3	order life cycle	configuration & order	order sequencing	planning and scheduling			picking, packaging	shipping
3.4	technology life cycle	planning	development	virtual testing			main-tenance	modernization
3.5	indirect functions	primary activities			secondary activities			
		Inbound & outbound logistics		marketing & sales	service	firm infrastructure	HR	technology development
4.1	learning environment	purely physical (planning + execution)		physical LF supported by digital factory	physical value stream of LF extended virtually		purely virtual (planning + execution)	
4.2	environment scale	scaled down			life-size			

### 11.29.1 Starting Phase and Purpose

The Learning Factory Laboratory at the Free University of Bolzano was founded in 2012 as a “Mini-Factory” with start-up funds from the Chair of Production Systems and Technologies in the research area Industrial Engineering and Automation (IEA). The name “Mini-Factory” was chosen as name for the learning factory laboratory because it should reflect the principles of lean and agile production in a small and realistic scale. Furthermore, the concept of small and distributed manufacturing systems (“mini-factories”) pursues the goal of producing mass-customized products on demand and in close proximity to the customer (Fig. 11.72).

In 2015, the Autonomous Province of Bolzano allocated a budget of 2.3 million euros to the Free University of Bolzano due to IEA's efforts to establish research and teaching competence in the field of Industrie 4.0 in Italy. These funds are planned for capacity building in the sense of suitable laboratory space, research personnel and investments in machinery and equipment. Due to the tight spatial situation in Bolzano, it took until 2017 to find a temporary solution to accommodate the learning factory in the city center. In the medium term, the learning factory together with a part of the university campus is to be relocated to a new building in the brand-new NOI Technology Park in the south of Bolzano.

### 11.29.2 Learning Environment and Products

The learning factory is divided into two different areas. One area comprises 3D printers for additive manufacturing and several numerically controlled machine tools in the form of a CNC machining workshop, which can be loaded and unloaded via a collaborative robot. This allows parts to be manufactured and then brought into the second area for assembly. There is a manual and hybrid assembly area with assembly stations from Bosch Rexroth, an assembly assistance system and a collaborative robot from UR. A mobile platform from Kuka equipped with a Kuka iiwa lightweight robot takes the semi-finished part to another automated area. There, automated assembly and packaging processes are carried out using a six-axis robot, a SCARA robot, and a delta robot, which will in future be connected via a transfer system. The various systems are connected as CPSs via a horizontal proximity and a vertical access network in a cyber-physical production system environment. Using VR and AR headsets and a virtual 3D data model, a digital mock-up of the production system can be generated and adapted in advance.

Currently, two different products are produced on the assembly line. On the one hand, a pneumatic cylinder and on the other hand a pneumatic impact wrench (Fig. 11.73). A product analysis is carried out at the beginning defining the process steps with an assembly precedence graph. After preparation of the inventory of individual parts, the practical implementation in the line, the balancing of the assembly





Fig. 11.72 Exemplary pictures and 3D virtual data model of the lab

tasks as well as several loops to increase efficiency in the production system are carried out.



Fig. 11.73 Produced pneumatic cylinder and pneumatic impact wrench in the Smart Mini-Factory

### 11.29.3 Operation

The use of the learning factory laboratory is divided into three parts. On the one hand, it is used for applied research and therefore serves for building up individual test setups. Secondly, it is used as part of the bachelor's and master's programs for industrial and mechanical engineering (mainly the lectures "Production Systems and Industrial Logistics" as well as "Industrial Automation and Mechatronics"). Thirdly, seminars on all aspects of Industrie 4.0 for industrial companies are offered (Fig. 11.74). The exercises and seminars are designed and conducted by researchers, postdocs, and PhD students. The industrial seminars allow a close contact with local industry and thus facilitate the transfer of knowledge from research to industry.

### 11.30 Best Practice Example 30: Teaching Factory: An Emerging Paradigm for Manufacturing Education. LMS, University of Patras, Greece

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## **Learning Factories**

Concepts, Guidelines, Best-Practice Examples

This book presents the state of the art of learning factories. It outlines the motivations, historic background, and the didactic foundations of learning factories. Definitions of the term learning factory and a corresponding morphological model are provided as well as a detailed overview of existing learning factory approaches in industry and academia, showing the broad range of different applications and varying contents. Learning factory best-practice examples are presented in detailed and structured manner. The state of the art of learning factories curricula design and their use to enhance learning and research as well as potentials and limitations are presented. Further research priorities and innovative learning factory concepts to overcome current barriers are offered. While today numerous learning factories have been built in industry (big automotive companies, pharma companies, etc.) and academia in the last decades, a comprehensive handbook for the scientific community and practitioners alike is still missing. The book addresses therefore both researchers in production-related areas, that want to conduct industry-relevant research and education, as well as managers and engineers in industry, who are searching for an effective way to train their employees. In addition to this, the learning factory concept is also regarded as an innovative learning concept in the field of didactics.

