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Educational Learning Factory of a holistic Product Creation Process

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Abstract

Future production faces challenges such as shorter time-to-market, high number of product variants and limited resources. To meet these challenges qualified employees are required. With the approach of learning factories methodological, social and personal competencies of employees are increased. For the education of methods, technologies and tools for the product creation a product lifecycle (PLC) approach is chosen which includes research fields such as Innovation Management, Engineering Methodologies, Production Management and Virtual Engineering to create a holistic practical learning framework based on a constructivism learning approach. The learning factory concept centers Systems Engineering (SE) as a structural element for projects by SE specific processes and role models.

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Keywords: Learning factory, Systems Engineering, Research fields, methodology

1. Introduction

Increasing global competition forces companies to constantly reduce the time-to-market of their products. This involves reducing not only the product development time but also the production time. However the increasing complexity of products, high numbers of product variants, limited resources and demographic change [2] are becoming the new challenges for an effective production. For managing these challenges, well trained and educated employees have to possess competencies of different disciplines.

The Product Creation Process (PCP) includes various phases to develop a complex product. Concepts like Industry 4.0 confirm the future product developmentbased on several disciplines such as mechanics, electronics and informatics. Research fields such as Innovation Management, Engineering Methodologies and Management, Integrated Production Management and Virtual Engineering deliver information, methods and techniques for the PCP. Mechatronic and cyber-physical products suffer from an increasing complexity. Systems Engineering (SE) is an methodology to coordinate and connect different disciplines for the development of complex projects or products [7,18].

Usage of conceptional approaches like SE challenges enterprises in terms of coordination, communication and the needs for a common understanding within interdisciplinary teams. For the implementation of approaches like SE employees must possess fundamental know-how of processes and characteristics of SE. One possibility to impart knowledge are practices of studies to educate systems engineers.

This paper deals with an educational approach of a learning factory focusing basically on the PCP, covering all phases from product ideas to manufactured products. Another important aspect is the integration of research fields. The aim of the educational concept is the increase of competence-oriented learning outcomes and the implementation of student centric methods for active application of theoretical knowledge. The attempt of the learning factory includes research fields being necessary for the PCP, but also takes the focus on the design methodology SE for a practical usage of processes and methods of SE which are rarely implemented in companies.

2. State of the art

The section shows the morphological approach of teaching methods by Steffen [13], the modified morphology for learning

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factories by Tisch [15], challenges for the development of competency which can be solved by educational methodologies such as learning factories and two examples for learning factories, away from resource efficiency and “Lean Production”.

2.1 Learning Factories

The didactical approach of learning factories has various definitions. The expression “learning factory” is composed of the words “learning” and “factory” which include different aspects. The first element involves an educational approach of learning and teaching. The second element “factory” describes the industrial environment which is necessary for the industry-related education [1, 16].

A classification of courses is possible with the generic morphology of teaching methods by Steffen [13]. A learning factory concept can be categorized by a modified variant of the teaching morphology developed by Tisch et al. [15].

Tisch et al. developed an approach for an action-oriented, competency-oriented learning factory. With the help of this approach, called Learning Factory Curriculum Guide, a learning factory design should be provided for the improvement of target groups´ competencies. The first part of the procedure, entitled “first didactic transformation”, focuses the required competency development by an analysis of target groups. Additionally for the competency development the second didactic transformation assigns suitable teaching methods by the morphology of teaching methods [14].

Additionally Adolph et al. describe challenges for the development of competency such as globalization, penetration of new technologies, more dynamic product lifecycles, limited resources, etc. and provide methods to handle challenges [2].

A various number of learning factories were established worldwide during the past years. The configuration differs by main topics for education like energy and resource efficiency or lean management [4, 8, 9, 10, 12]. The following paragraphs (2.2, 2.3) provide two examples of topic specific learning factories.

2.2 LPS Learning Factory Bochum

The LPS Learning Factory in Bochum deals with three different topics: process optimization, resource efficiency and management and organization. These topics include methods of “Lean Production” and material and energy reduction. Management and organization includes investigations of codetermination, work councils and integration of handicapped or older employees in the production process.

Bender et al. (Chair for Product Development, Bochum) describe an additional methodology for an enlargement of the learning factory concept, called Learning Factory 2.0 [3]. The holistic procedure gives the possibility to investigate and impart communication and cooperation between product development and production. The lecture for students is conceived as a business game, including virtual models and simulations. The FMEA method acts as a communication tool between production and product development groups to improve processes [3, 8, 17].

2.3 Demonstration Factory Aachen

Schuh et al. developed a holistic approach at the RWTH Aachen. They focuses onfuture production in context of Industry 4.0 and point out the requirements for a learning factory. A specific focus is defined for technological and process changes by Industry 4.0. An emphasis on work-based learning implies influencing factors (product, process, personal), as well as technical (information, tools, material) and organizational (learning methodology, employee organization, work task) levers. By an analysis of trends, Industry 4.0 characteristics were identified and combined with the work-based learning approach. For the validation of use cases based on Industry 4.0 such as human-machine interfaces, context-sensitive provision of information and virtualization of physical objects, the already existing Demonstration Factory in Aachen is used. It includes machines for sheet metal forming and joining of automotive body structures as well as stations for manual assembly. [12]

2.4 Research fields in PCP

The research field “Strategic Planning and Innovation Management” deals with the analysis and prediction of social and economic environment being realized with scenario technique. Another important aspect is the development of suitable business models with Business Model Canvas, especially in context of Industry 4.0. The implementation of an innovation culture in enterprises is created by innovation workshops with creativity techniques.

SE provides processes and methods which accompany all phases of the PCP. A specific aim of SE is the linkage of different disciplines such as mechanics, electronics and informatics. Approaches of design methodology such as VDI 2206 or agile design methodology are possibilities to increase efficiency of design and production processes. Nowadays innovation can often only be reached at the expense of high complexity of the technical system. For example mechatronic and cyber-physical systems require interdisciplinary collaboration. Therefore methodologies dealing with these complexities gain importance. SE is a promising approach to deal with complexity, especially for communication and collaboration of various disciplines.

“Production Management and Automation Technology” deals with the early implementation of production planning and the development of cyber-physical decentrallcontrolled production systems. Especially the communication of decentrally controlled systems is a fundamental research topic. Another important aspect is the coexistence of human beings and machines in production environments.

The research field “Virtual Engineering” includes the support with digital tools, innovative technologies and a holistic IT- infrastructure for the PCP. One aspect is the integration of development software to increase the penetration of virtual and decrease of physical prototypes. Another aspect