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Learn to shape the digital transformation: the design approach of a learning factory for industrial engineers

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Abstract

The digital transformation in economy changes the way we do business, manufacture products, transport goods, exchange information, or deliver services due to advances in automation and digital technologies. This, in turn, requires competent individuals to shape this transformation responsibly and sustainably. One way to impose the needed competencies to do so in a realistic manner is made possible by learning factories. Thus, our work describes the design approach of such a learning factory at a university of applied sciences. The starting point of our concept are the required competencies of (future) industrial engineers from theoretical and practical point of views. Requirements of further stakeholders like students and participating university chairs are also considered. Finally, we also present several envisaged teaching scenarios meant to depict altogether a holistic engineering-to-order process within this learning factory to address the identified requirements. To do so, the scenario encompasses all steps within the value chain from product design over manufacturing, maintenance, intra-logistics and assembly, applying various automation and digital technologies wherever possible. The contribution of our work is mainly twofold. First, we design a learning factory and teaching scenarios. Second, our teaching scenario focuses on critical thinking about digital technologies rather than sole experience and application in the learning factory. Overall, the concept implements the insights from our latest research projects with respect to Industry 4.0 and is work in progress.

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Keywords: digital transformation; industrial engineering; competencies; learning factory; teaching scenarios

1. Introduction

Automation and digitalization play a significant role in the manufacturing industry. These efforts culminate today in what is also known under the term "Industry 4.0" (I4.0) [1]: the networking and communication of all units involved in the production in real-time – man and machine. Due to the associated, sometimes far-reaching changes in the entire production process, the question of which competencies are required of the employees also plays an important role in this context, especially when whole businesses are strategically transformed by implementing digital technologies. Especially in geographical regions with few manufacturing companies compared to the national average, a small proportion of large enterprises, a low population density, a low proportion of young educatable people, and major ongoing social and economic transformation processes, a key aspect to ensure competitiveness and sustainable development is education [2]. Therefore, we are proposing the design of a learning factory for industrial engineers at a university of applied sciences in the German region of Upper Lusatia. The proposed learning factory design addresses the issues of low training resources of the local small and medium-sized enterprises (SMEs) by educating pupils, students, and employees collaboratively and hands-on with state-of-the-art I4.0 concepts to learn to shape the digital transformation in business and society successfully, critically, and sustainably. Learning factories can most efficiently meet the need for practical and competence-oriented teaching for technical education with regard to the digital transformation and I4.0. Therefore, we are addressing in this paper the question, how a learning factory should be designed to address and combine both (1) regional industrial, educational, and societal requirements, and (2) global challenges like Industry 4.0 and

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digital transformation. In the following, the respective design approach, learning factory, and teaching scenario concept are described (Section 2), before the results are discussed and an outlook is given in Section 3.

2. A learning factory for the digital transformation

2.1. Design approach

Our design approach of the learning factory for digital transformation is based on three major pillars: (1) recent research and development (R&D) efforts in I4.0 and digital technologies [3–6], (2) the integration of the relevant stakeholders, as well as (3) innovative, state-of-the-art teaching scenarios [7, 8]. The respective work in each of these pillars is conducted in different R&D projects and is thus not necessarily undertaken subsequently. The methods applied for the design approach include literature reviews [3, 9] and surveys [3, 4] to derive the requirements (1) and teaching concepts (3), as well as stakeholder workshops and analytic hierarchy process (AHP) for prioritization of teaching contents and formats (2) [5]. Note-worthy requirements identified for the learning factory concept and respective learning scenarios include the importance of critical thinking, and social responsibility in terms of implementing digital technologies in production and logistics [10]. Furthermore, flexibility is required not only from students, i.e. future industrial engineers, but also concerning the factory equipment: the factory should be designed modularized to be easily adapted to new requirements, and it should make use of remote teaching possibilities [7, 8].

2.2. Resulting concept

Following classifications of prior studies like in [11–13], our resulting first learning factory concept can be roughly described as a learning factory in the narrow sense that represents a real value chain with a physical product as result, in our case namely a planetary gear [14]. The mode of teaching is mainly on-site with remote aspects. The first teaching scenarios within this learning factory are enhancing the project-based learning approach in [14] by implementing as many as possible steps of a real engineering-to-order process within a manufacturing company. By doing so, many different approaches and methods from disciplines such as engineering, production, logistics, operations management, and information systems are represented, while additionally critically reflecting technologies like augmented reality (AR) or additive manufacturing (Table 1).

Table 1. Project-based learning scenarios depicting a simplified overall engineering-to-order process.

No.	Scenario	Used technologies, methods, or concepts	Learning goals
1	Assessing requirements	Electronic documents, enterprise resource planning (ERP) systems, computer-aided design (CAD)	Assessing the order (e.g., quantity, delivery date), including engineering requirements (e.g., required parts to engineer)
2	Planning	Project management tools	Resource planning and allocation applying project management methods
3	Designing parts	CAD software	Training with CAD tools for designing mechanical parts [14]
4	Printing parts	CAD software, 3D printer	Training with 3D printer for handling and transferring CAD data to the 3D printer, and equipping it [14]; additionally, reflecting on social and ecological aspects of additive manufacturing [10]
5	Maintenance	3D printer, AR	Training with 3D printer for maintenance purposes [15]
6	Setting up commissioning systems and procedures	Lean Management, pick-by-voice, and pick-by-vision commissioning systems	Basics of Lean Management approaches for laying out logistics systems for an assembly workplace; setting-up different commissioning procedures; compare and reflect the different logistics systems in terms of performance (including human factors)
7	Preparing assembly workplace	Lean Management	Basics of Lean Management approaches for laying out assembly workplaces
8	Manual assembly	Video- and AR-based assistance systems	Comparing and critically reflecting on different assistance systems in assembly in terms of performance (including human factors) [6]
9	Quality assurance	Quality management, Lean Management	Basics of quality management and discussing measures for improvements of the previous processes
10	Distribution	Distribution logistics	Designing and comparing different distribution channels
11	Project closure	Quality Management, Lean Management	Basics of quality assurance, applying continuous improvement process (CIP)

3. Conclusions and outlook

In this short paper, we presented the design approach for a learning factory for the digital transformation at a university of applied sciences in the German region of Upper Lusatia. The design is grounded in the requirements of I4.0 and the use of the respective digital technologies, the needs of the (local) stakeholders, and the expectations concerning up-to-date didactical approaches in higher education and further training. To address the needs to competently shape the digital transformation, a concept depicting a holistic engineering-to-order process is simplified and transferred into several teaching scenarios within the learning factory. So far, modules of the learning factory are already partly implemented at the Zittau/Görlitz University of Applied Sciences. Individual learning scenarios like comparing different commissioning and assistance systems have also already been tested with several student groups from (industrial) engineering, giving the teachers very positive qualitative feedback about the discussion and application of AR at the final course evaluation. In short- and mid-terms, the learning factory will gradually be extended in close collaboration with the stakeholders and partners, as well as the learning scenarios further tested and implemented into the curricula.

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References

[1] H. Kagermann, W. Wahlster, J. Helbig, Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Final Report of the Industrie 4.0 Working Group, Securing the future of German manufacturing industry, (2013).
[2] W. Berger, S. Lademann, J. Schnellenbach, S. Weidner, S. Zundel, Standortpotentiale Lausitz: Studie im Auftrag der Zukunftswerkstatt Lausitz, Ein Projekt der Wirtschaftsregion Lausitz, (2019).
[3] S. Keil, F. Lindner, J. Moser, R. von der Weth, G. Schneider, Competency Requirements at Digitalized Workplaces in the Semiconductor Industry, Lecture Notes in Electrical Engineering, Digital Transformation in Semiconductor Manufacturing: Proceedings of the 1st and 2nd European Advances in Digital Transformation Conference, (2020) 88–106.
[4] F. Lindner, K. Mühlan, D. Winkler, F. Naumann, S. Keil, Die Bedeutung “klassischer” Kompetenzen in der digitalen Transformation, 17. Workshop on e-Learning, (2019).
[5] F. Lindner, D. Winkler, K. Mühlan, S. Keil, Digitale Kompetenzen für zukünftige Wirtschaftsingenieurinnen und -ingenieure: ein Stakeholderranking mithilfe des Analytischen Hierarchieprozesses (AHP), Online-Pre-Conference 2020 der 15. Ingenieurpädagogischen Regionaltagung 2021, (2020).
[6] F. Lindner, D. Winkler, A. Müller, K. Mühlan, S. Keil, Assessing the Impact of Information Assistance Systems on a Worker Level: A Pre-Study towards an Evaluation Framework, Mensch und Computer 2020: Workshopband, (2020).
[7] D. Winkler, F. Lindner, Lehren und Lernen mit multimedialen Lehrbriefen, 18. Workshop on e-Learning: Tagungsband, (2020).
[8] D. Winkler, F. Lindner, S. Keil, K. Mühlan, “Digital ist besser? Ja, aber!”: Chancen technologiegestützter Lehre am Beispiel des Integrierten Modells des Text- und Bildverstehens, 17. Workshop on e-Learning, (2019).
[9] S. Keil, K. Mühlan, D. Winkler, F. Lindner, Digitale Kompetenzen in der Hochschullehre: “10.000 Schritte in den Fußstapfen eines Pickers”, 14. Ingenieurpädagogische Regionaltagung 2019, (2020).
[10] S. Keil, D. Winkler, “Werte lehren”: Studierende übernehmen soziale und ökologische Verantwortung und lernen dabei Projektmanagement, Sonderedition des HDS.Journals zur 48. Jahrestagung der Deutschen Gesellschaft für Hochschuldidaktik: Regeneration Hochschullehre, (2019).
[11] E. Abele, J. Metternich, G. Chryssolouris, W. Sihn, H. ElMaraghy, V. Hummel, F. Ranz, Learning Factories for Research, Education, and Training, Procedia CIRP, 32 (2015) 1–6.
[12] M. Tisch, C. Hertle, J. Cachay, E. Abele, J. Metternich, R. Tenberg, A Systematic Approach on Developing Action-oriented, Competency-based Learning Factories, Procedia CIRP, 7 (2013) 580–585.
[13] F. Baena, A. Guarin, J. Mora, J. Sauza, S. Retat, Learning Factory: The Path to Industry 4.0, Procedia Manufacturing, 9 (2017) 73–80.
[14] M. Spitzer, M. Ebner, Project Based Learning: from the Idea to a Finished LEGO® Technic Artifact, Assembled by Using Smart Glasses, Proceedings of EdMedia: World Conference on Educational Media and Technology, (2017).
[15] M. Spitzer, M. Rosenberger, A. Stocker, I. Gsellmann, M. Hebenstreit, M. Schmeja, Digitizing Human Work Places in Manufacturing Through Augmented and Mixed Reality, Lecture Notes in Electrical Engineering, Digital Transformation in Semiconductor Manufacturing: Proceedings of the 1st and 2nd European Advances in Digital Transformation Conference, (2020) 75–87.