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# Competency Models for the Digital Transformation and Digitalization in European SMEs and Implications for Vocational Training in Learning Factories and Makerspaces

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## Abstract

In Europe, SMEs account for the majority of businesses and are important contributors to job creation and global economic development. The digitalization of business processes of manufacturing companies offers enormous potentials in terms of productivity. Nevertheless, the digitalization level of SMEs is low compared to large enterprises, as SMEs lack in resources in terms of time, money, and personnel. Another reason is, that SMEs are lacking in qualified workforce for the digital transformation. Learning factories and makerspaces offer valuable learning environments to transfer competencies for the digital transformation and digitalization. In this paper the results of an interview study with SMEs are presented that included the investigation of required competencies of the workforce in this field. Moreover, the didactical transfer of one of the required competencies is shown and implications for trainings in learning factories and makerspaces are derived. In conclusion a structured analysis of available and required competences should be performed in order to provide tailored, modular training programs using digital infrastructures like learning factories and makerspaces.

## Keywords

learning factory, makerspace, digitalization, vocational education and training

## 1 Introduction

Manufacturing companies in Europe are currently facing major challenges, such as volatility and uncertainty (Würzburger, 2019). Digitalization is offering multiple opportunities, especially for the manufacturing industry. By implementing digital technologies, it is not only

possible to increase productivity and efficiency in the value chain, but also to meet the challenges in a volatile business environment (Schuh et al., 2017). Several studies show that small and medium-sized enterprises (SMEs) in particular are still clearly behind large companies in terms of digital transformation and the use of digital technologies (Hölzl et al., 2019). SMEs in Austria are struggling to take advantage of the opportunities presented by digitization in the value chain (Arthur D. Little, 2017; Gangl & Sonntag, 2020). It was found in research studies (Lindner, 2019; Hölzl et al., 2019) that this might be due to the fact that SMEs have limited time, financial and personnel resources and the management as well as employees lack in competencies regarding the digital transformation and digitalization. As a result, it is of particular importance to investigate the competencies needed in order to support the digital transformation and the use of digital technologies along the value chain (Buer et al., 2020). (Digital) competencies can be subsumed in competency models. Lucia and Lepsinger (2003, p. 211) define a competency model as "a descriptive tool that identifies the competencies needed to perform a role effectively in the organization and help the business meet its strategic objectives". Prior to the interview study, several competency models and relevant digital competencies in SMEs were analyzed (e.g., Buer et al., 2020; Eller et al., 2020). It can be concluded that there is a lack of focus on current challenges in SMEs, such as volatility and uncertainty. Moreover, these models do not take into regard the value adding process but they primarily focus on leadership. It has been shown that competency requirements of workers of SMEs differ from the demands of larger companies. In larger companies the usage of technologies is in the focus of attention. The workforce in SMEs needs to have more knowledge on process and data analytics (acatech et al., 2016). Nevertheless, most trainings found in a literature analysis are either independent of company size or focus on larger companies. Furthermore, there are only few practical training courses that concentrate on the practical implementation of digitalization (Block et al., 2018). Traditional teaching methods show lower effectiveness in terms of developing competencies of students as well as of the workforce for the current and future value creation processes, compared to trainings in learning factories or makerspaces (Abele et al., 2015; Cachay et al., 2012).

The goal of this paper is to derive required competencies of the workforce in SMEs based on 12 expert interviews with Austrian SMEs and demonstrate how these competencies can be developed in learning factories and makerspaces.

Therefore, the following research questions are defined:

RQ 1. Which are important competencies for digitalization and digital transformation in the value chain of small and medium-sized manufacturing enterprises in Austria?

RQ 2. What are implications for the vocational training in the field of digital transformation and digitalization in learning factories and makerspaces?

In the following, competency models in general and the transfer of competencies in SMEs are discussed. In a next step, learning factories are presented as learning environments in vocational training. Another chapter is devoted to an interview study with the goal to collect requirements for employees in the context of digital transformation and to contextualize the resulting data with an adequate competency model. The derivation of a competency is used as an example to demonstrate how sub-competencies can be described and how these can be transformed into concrete actions.

## 2 Competency Models

Following Lanza et al. (2018), the actors' competencies determine the structure for a volatile orientation of companies in dealing with tasks that Industry 4.0 places on them. The aim of the

project "Voladigital"[1] is, on the one hand, to define the digital and volatile challenges of SMEs and, on the other hand, to model the necessary, primarily digital competencies of employees and to evaluate them accordingly. It is first necessary to gain a uniform understanding of competencies for this work in order to develop a competency model focusing digital competencies that is adequate for SMEs. The inflationary use of the term "competency" poses a dilemma with regard to systematization and the development of a problem context and problem differentiation (Moser, 2014, p. 18). Rolf Arnold and Ingeborg Schüßler (2008) differentiate (1) the subject orientation of the term, thus distinguishing it from the term "qualification", which is socially determined; (2) the holism, because the term brings together cognitive, evaluative, and emotional-motivational aspects of action (Erpenbeck & Heyse, 1996, p. 55); and (3) self-organization (Reetz, 1990; Erpenbeck & Heyse, 1996), because operational task assignments require workers to take on organizational and dispositive tasks that go in the direction of self-organized action. The term "competency" is associated with the problem-solving and orientation skills that enable people to succeed in open, complex and unpredictable situations (Erpenbeck & Heyse, 1996). Based on the understanding of competency described above, competencies should relate to employees, i.e. to the holistically perceived human being. In this sense, context-specific activities and tasks are to be described, which can be mapped in Industrie 4.0 domains. The challenge of a competency model is to define structures and characterize levels (Klieme & Leutner, 2006, p. 883). In this context, it must be clarified which and how many competency dimensions can be differentiated, and which concrete situational requirements people can master at which level of a competency. With regard to the degree of specification, Gessler (2010, p. 54 ff.) describes three categories of competency models, which are presented here.

**Table 1**
*Competency models following Gessler (2010)*

| | **General Competency Models** | **Enterprise-specific Competency Models** | **Domain-specific Competency Models** |
|---|---|---|---|
| Term | One-size-fits-all | Multiple-job approach | Single-job |
| Specification | Non-enterprise-specific | Medium level of abstraction, non-specific to the profession, formulated in rather general terms, but enterprise-specific | Work processes are analyzed and competency requirements are described by means of studies, necessary competencies in the work process are recorded |
| Example | Kompetenzatlas Heyse & Erpenbeck (2004) | Arises discursively, example see below | Competency model for electronics technician for automation technology (e.g., Link & Geißel, 2015) |
| Development | Mapping of general competencies | Description of competencies required in the enterprise due to current and future requirements, discursive emergence | Larger-scale surveys in occupational fields |

General competency models (one-size-fits-all) are constructed unspecifically for enterprises. The competency atlas by Heyse and Erpenbeck (2004) can be cited as an example, which divides competencies into four main dimensions (personal competencies, social-communicative competencies, technical and methodological competencies, activity and action competencies) and further differentiates these into 64 subdimensions. The problem with this model lies in the largely incoherent selection and unclear assignment of the sub-competencies to the main

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dimensions. In addition, some of the subdimensions overlap. Nevertheless, the model offers a plausible framework for classifying context-related competencies. Enterprise-specific competency models (multiple-job approach) have a medium level of abstraction. Based on abstract dimensions such as personal competencies, social competencies and professional competencies, company-specific guidelines are discursively related to these as "cross-sectional dimensions". The advantage of this model lies in its discursive emergence, whereby the demand for competencies, as are subject orientation, self-organizational ability and holism, can be met. Possible risks of this model are lengthy and uncontrollable processes of consensus building regarding descriptions of competencies, domains and levels. Domain-specific competency models (single-job) are described as the most specified models. Work processes are recorded and analyzed, and competencies required for the work process are derived from them. The rigidity of the task descriptions can be seen as a disadvantage, making situational flexibility and self-organized development of the actors difficult. Based on an extensive survey process, which will not be discussed in detail in this article, the "Voladigital" project will identify the competencies of employees required for SMEs and map them in a model. In order to integrate competencies in the context of Industrie 4.0 into this model, the "multiple-job approach" model appears to be promising because it has a medium level of abstraction, which offers openness for company-specific objectives. Based on a competency model yet to be fleshed out in the project, the next step is to provide effective learning environments that enable the development of employee competencies in SMEs. Learning factories and makerspaces, as demonstrated in the following chapter, support the development of competencies as described above.

## 3 Learning Factories and Makerspaces as Learning Environments

The term learning factory was first introduced in 1994 in the course of a research grant to the Penn State University, with the aim of creating an infrastructure at the university for interdisciplinary, interactive projects with a strong industrial connection. In recent years, however, the term has been strongly developed by European universities and initiatives such as the "Conference on Learning Factories". In the new understanding, the term learning factory is used for systems that include elements of learning or teaching as well as a production environment (Wagner et al., 2012, p. 110). Learning factories can take on a variety of configurations, but the processes and technologies used are chosen to be close to the reality (Abele et al., 2017, p. 2), making them a suitable approach to education and training in realistic manufacturing environments (Abele et al., 2015, p. 804). Due to the practical teaching concept, they offer the potential for competency development in a self-directed learning process (Müller-Frommeyer et al., 2017, p. 307).

The term makerspace is closely linked to the Maker Movement and its individuals, the makers, who are generally groups or individuals who produce objects based on their own ideas. The focus here is not on economic advantages, but rather on the interest in creating new products or individualizing existing products (Friessnig et al., 2016, p. 48). A makerspace is the center or also the workspace where a group comes together to work on projects (Hatch, 2014, p. 18). Besides knowledge exchange with like-minded people and social aspects, makerspaces also provide low-threshold access to digital production facilities. The offer in typical makerspace facilities varies and ranges from digital production machines (e.g., 3D printers, laser cutters, vinyl cutters) to woodworking equipment (e.g., CNC milling machines for wood, saws, drills) and metalworking equipment (e.g., welding machines) to electronic equipment (e.g., soldering stations) or textile machines (e.g., sewing machines, textile printing machines) (Böhm et al., 2015, p. 4).

A learning factory as a learning environment has authentic, multi-station processes, a changeable setting that corresponds to a real value chain, a physically manufactured product, and a didactic concept that enables learning through one's own actions on site. In general, the purpose

of a learning factory is to enable learning in production environments, and it is not only aimed at students as a target group but is also explicitly available for advanced training of industry employees (Abele et al., 2017, p. 809). This offers an ideal learning environment for teaching competencies relevant to production environments and is adaptable enough to also cover digital and future-relevant topics. Usually, the teaching concepts of a learning factory are oriented towards experiential learning as well as active action-oriented learning. Thus, instead of a mere reproduction of information, the focus is on developing understanding of the concepts taught (Crawley et al., 2014, p. 22). Research shows a positive effect of learning factories in terms of knowledge retention and transfer opportunities, especially compared to traditional teaching methods (Cachay et al., 2012, p. 1151).
Makerspaces pursue a similar teaching and learning concept and focus on learning experiences through active "making" or "building" of tangible objects and products. They have developed into new centers of learning and, in addition to their own infrastructure, rely primarily on a worldwide network for the exchange of knowledge and experience, on low-threshold access to (production) tools, on openly accessible project libraries and on a broad range of training and support (Böhm, 2018, p. 80).

## 4 Methodology

The study presented is a part of the project "Voladigital". In the first step of the research project, the analysis phase, challenges, and competency requirements with regard to digitization were investigated on the basis of knowledge from previously conducted projects as well as a qualitative preliminary study. During this study, experts from consulting firms and companies in the manufacturing industry were interviewed. Based on this, a questionnaire was developed, in which competency requirements and challenges were investigated. These were evaluated with the help of descriptive statistical methods. In the solution development phase, it was evaluated how these competencies can be taught. Theoretical training contents were created, which are to be made available to all SMEs free of charge in future on an intelligent e-learning platform. This will teach how digitization can be used and implemented sensibly. In addition, knowledge about digital technologies and other skills will be determined, depending on the survey. Based on the individual requirements, the intelligent learning system can personalize modules with teaching content as well as quizzes. In the practical part of the training concept, theoretically learned content is presented in the LEAD Factory, a learning factory, and the Schumpeter Laboratory for Innovation. Both infrastructures are used to cover the spectrum from product development (Schumpeter Laboratory for Innovation) to (serial) production (LEAD Factory).

## 5 Interview Study

First, a literature review was performed on the competencies and the competency models regarding digitalization and the digital transformation in the value creation process in the manufacturing industry. Thereby, 30 literature sources were identified and analysed. This literature review was the basis for the development of the interview guideline. In order to select suitable interview partners, the procedures of theoretical and purposive sampling were performed. Theoretical sampling is an iterative process in which data gathering and data analysis alternate while the sample size has not been determined in advance (Birks and Mills, 2012). It was decided to interview general managers from SMEs in Austria. When selecting the sample, care was taken to ensure that companies from different industries, with different numbers of employees and with different levels of sales were included. Concerning the business branches, following industries were included: metal production and processing, manufacturing of fabricated metal products, manufacturing of computers, electronic and optical products, manufacturing of electrical equipment, manufacturing of motor vehicles, trailers and semi-trailers and other transport equipment. The number of employees of the interviewed SMEs ranged from 15

to 180. The turnover is between € 2 Mio and € 45 Mio. The interviews were performed from June to September 2020 using videoconferencing software. One interview partner was interviewed personally. The length of the interviews ranged from 0.6 up to 1 hour.
The interview guideline was created according to the SPSS procedure of Helfferich (2009). **S**: In order to create a guideline, it makes sense to first collect a large number of questions in an open brainstorming session. **P**: If there is a large pool of questions, the questions have to be reduced and must be checked for suitability; all points that do not fit must be deleted. **S**: The remaining questions have to be sorted by content/theme as well as by open-ended narrative prompts, maintenance questions, and specific follow-up questions. **S**: Finally, the checked and sorted questions must be subsumed into a guideline, i.e., classified or subordinated. The guideline was structured in different types of questions according to Helfferich (2009).

- Leading questions: This serves as a narrative prompt/stimulus and is formulated very openly: "Please tell me how …?"
- Up-keeping questions: It does not provide a new topic, but maintains the narrative flow or provides impulses for associative thoughts e.g. "What else can you think of?"
- Concrete follow-up questions: Here, follow-up questions can be formulated about aspects of content that have not yet occurred in the conversation.

The interviews were analyzed qualitatively with the help of the software MAXQDA according to the qualitative content analysis of Mayring (2010). The coding system was based on a combined deductive and inductive system. Categories include, amongst others, general competencies, competencies in production and competencies in product development. As a result, the competency model for digitalization and digital transformation can be derived. As a last step, the implications for vocational trainings in learning factories and makerspaces are derived. The term learning factory is composed of "learning" which stands for the overall objective, the development competencies, and "factory" for the replica of a realistic production site. A learning factory is a special learning environment in which (value creating) processes and technologies are modelled based on a real industrial company. The didactical concept of learning factories grounds on experimental and problem-based learning. Participants are able to improve processes and experience the improvement in the learning environment (Abele et al., 2015). Makerspaces are places where makers can come to use tools alone or together or to carry out projects. Moreover, they are suitable learning environments in the field of product development and innovation (Peppler et al., 2016). The findings are based on a study and on experiences in makerspaces designed and operated by the Graz University of Technology.

## 6 Findings

In the literature, competencies are described in connection with digitization that the workforce of the future should have, whereby creativity, flexibility, agility, the ability to innovate, the exchange in networks, working in a team and the implementation of ideas are mentioned above all. The most relevant technical competencies include interaction with digital technologies, data and information processing and analysis, and ICT competencies. To cluster these competencies according to Erpenbeck and von Rosenstiel (2007) proved to be suitable. Several competencies were derived that are required in SMEs for digitalization and the digital transformation. These competencies are listed in Table 1 and explained. Moreover, they are categorized in the competency model of Erpenbeck and von Rosenstiel (2007).
Personal competencies **(P)**: As the disposition of a person to act reflexively in a self-organized manner. Self-assessment, productive attitudes, value attitudes, motives, motivation to develop and learn creatively in the context of work and outside it. Activity- and implementation-oriented competencies **(A)**: As the disposition of a person to act in an active and holistic self-organized

way and to direct this action towards the implementation of intentions, plans and intentions. This disposition thus captures the ability to integrate the own emotions, motivations, abilities and experiences and all other competencies into one's own will drives and to successfully realize actions. Professional-methodical competencies **(M)**: As the disposition of a person to act in a mentally and physically self-organized manner when solving factual-objective problems, i.e., to creatively solve problems using technical and instrumental knowledge, skills and abilities, and to classify and evaluate knowledge in a sense-oriented manner. Social-communicative competencies **(S)**: As the disposition to act in a communicative and cooperative self-organized manner, i.e., to cooperate creatively with others, to behave in a group- and relationship-oriented manner, and to develop new plans, tasks and goals.

**Table 2**
*Required competencies of employees in SMEs*

| Competency | Explanation of the competency | Category of competency (Erpenbeck & von Rosenstiel 2007) |
|---|---|---|
| Flexibility | Employees need to show personal flexibility in terms of work time, type of work and what technology they work with. | P |
| Working with sensors | In order to gain value through data, data needs to be collected. Therefore, basic knowledge on sensors and how to apply them are required of employees. | A |
| Work with data | Collected data needs to be analyzed and interpreted in order to gain value (improved processes, higher productivity etc.). | A |
| Digital production planning and controlling | Employees should have the ability to perform production planning and controlling digitally and need to be able to work with the corresponding software. | M |
| Process understanding and process analysis | There is a need to be able to understand the process as this is the basis for process improvements. Therefore, employees need to be able to analyze the value creation process from innovation to services. | M |
| Basic knowledge regarding digital technologies | There needs to be a basic knowledge on state-of-the-art digital technologies. Employees need to know about the availability and area of application of various technologies. | M |
| Problem solving | Methods of problem solving need to be known and applied by employees in order to overcome problems in the value creation process. | M |
| Development of a digital strategy/roadmap | Employees need to be able to develop a digital strategy/roadmap in order to be able to implement digital technologies purposefully. | M |
| Interdisciplinary collaboration | Employees need to be able to work with software and hardware developers. In the company, people need to be able to work together at different hierarchical levels and also with other departments. | S |

In the following an example demonstrates the didactical transfer of the competency “Problem solving” according to Tisch et al. (2015).

**Table 3**
*Didactical transfer of competency problem solving*

| | Subcompetencies | Actions | Knowledge Base |
|---|---|---|---|
| Process understanding and process analysis | Participants are able to describe a problem. | Participants describe a problem occurring in the learning factory. | Basic knowledge on how to describe a problem<br>Methods e.g. 5W2H |
| | Participants have the ability to define a target. | Participants define a target state. | Basic knowledge on target formulation (SMART Targets) |
| | Participants have the ability to analyze a problem (Root Cause Analysis). | Participants perform a Root Cause Analysis on the problem. | Methods of Root Cause Analysis<br>(5 Why's, Fishbone diagram) |
| | Participants have the ability to solve a problem (with the help of digital tools). | Participants perform solving (with the help of digital tools). | Problem Solving Methodology (A3) |
| | Participants have the ability to create an action plan. | Participants create an action plan. | Brainstorming<br>Multi-Criteria Analysis<br>Portfolio chart |
| | Participants are able to define standards and perform basic knowledge management. | Participants define a standard and have plan for knowledge management. | Definition of standards<br>Basic knowledge of knowledge management |

## 7 Answering the Research Questions and Conclusion

RQ 1. Which are important competencies for digitalization and digital transformation in the value chain of small and medium-sized manufacturing enterprises in Austria?
From our qualitative interview data, we derive competencies which are mapped in Table 2. These were categorized according to Erpenbeck and von Rosenstiel (2007). An example of the didactical transfer of a competency was shown. RQ 2. What are implications for the vocational training in the field of digital transformation and digitalization in learning factories and makerspaces? The goals and potentials of digitalization and the digital transformation in SMEs are meeting customer needs, creating new (digital) business models to generate more revenue through services and new innovations, increasing productivity in manufacturing, and increasing flexibility and agility. Concerning challenges regarding digitalization and the digital transformation, a lack of resources (money, time, and personnel), missing competencies and a missing strategy needs to be pointed out. Interviewees of SMEs were also asked regarding requirements for trainings. The following implications for trainings in learning factories and makerspaces can be derived.

- It is important to communicate in the trainings, why digitalization and the digital transformation are important for the company. Therefore, there is a need to show value creation improvements from innovation (makerspace) to the learning factory (production) based on digitalization, with the requirement that both the learning factory and also the makerspace need to be adaptable in terms of processes.
- Another requirement is that best practice examples need to be included.
- Trainings need to include all steps of the value creation process for a better process understanding. Therefore, it is important to include makerspaces as well as learning factories. Also the interface between the two infrastructures – from innovation to production (ramp-up management) – needs to be incorporated in trainings.

As SMEs lack in resources (time, money, personnel) it is important that trainings suit the companies. Therefore, trainings in learning factories and makerspaces need to be modularized and based on requirements. These modules need to be chosen for individual trainings. In a further step, the competencies derived from the interview will be analyzed and based on that, trainings in learning factories and makerspaces will be developed.

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