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Holistic approach for human resource management in Industry 4.0

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Abstract

To cope with knowledge and competence challenges related to new technologies and processes of Industry 4.0 new strategic approaches for holistic human resource management are needed in manufacturing companies. Due to the continuous automation of simple manufacturing processes, the number of workspaces with a high level of complexity will increase, which results in the need of high level of education of the staff. The challenge is to qualify employees to shift their capacities to workspaces with more complex processes and ensure the retention of jobs in changing working environments. A strategic approach for employee qualification is described in this contribution.

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Keywords: Industry 4.0; human resource management; competence development; qualification

1. Introduction

1.1. Actuality and relevance

In a globalized world with highly interconnected processes, companies are facing an increasing number of challenges to cope with. With competitors from all over the globe, innovation capacity and a short time-to-market become essential [1, 2]. Furthermore, the markets are becoming progressively volatile and heterogeneous due to constantly changing customer expectations and needs, such as customized products on demand [2, 3]. In order to fulfill those expectations, smart production systems are put in place to create the required flexibility and capacity. Simple and monotonous processes are being automated, while other processes become more complex and intertwined. Therefore, qualification strategies for the current workforce are required. Employees need to become enabled to take on more strategic, coordinating and creative activities. In addition, altering social values of employees and demographic change towards an accelerated aging of the society creates further need for action [4].

1.2. Research questions

In order to face those challenges successfully, the strategic management of competences becomes essential. This paper aims to present the development of a competence model and shows an approach of how companies can make use of it to meet arising challenges in Industry 4.0. Along the process of the model development the following research questions will be answered: What are general challenges companies will have to face in Industry 4.0? How do those challenges influence existing and future jobs as well as their related workflows? Which core competencies must employees possess in order to fulfill their current or future job? How can the competence model help a company to maintain a well-qualified workforce?

1.3. Methodology

The first part of this paper serves as theoretical foundation by pointing out the relevance of human resource management and competence development for a company's strategy. The second part describes the development of the holistic competence model. First, main challenges in Industry 4.0 are

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identified by conducting an extensive literature review. Based on a further analysis of those challenges, it is possible to derive a list of essential core competencies for employees. This list will be reinforced by comparing it to the most actual and relevant studies concerning future work competencies. The next step includes the visualization of the identified core competencies. Those three steps of the model development symbolize the pillars of the methodology shown in Figure 1.

The third part highlights the potential applicability of the developed competence model. It is presented how the model can be used for an Industry 4.0 readiness analysis of employees and how qualification strategies can be derived.

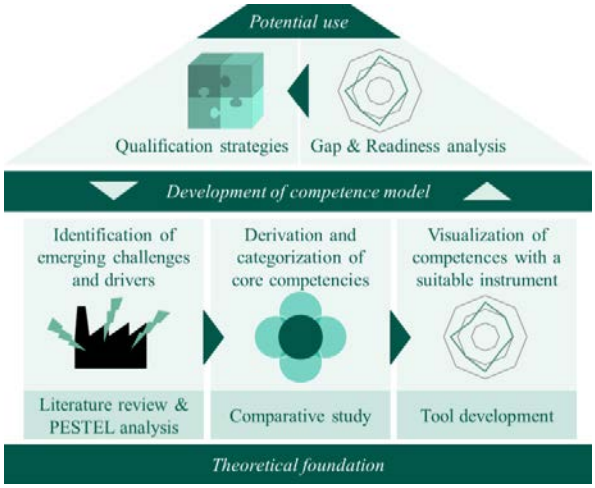

Figure 1: Methodological approach

2. The role and importance of human resource management for the corporate strategy

An organization's performance and competitiveness greatly depend on how its employees are managed. A concept concerning all activities regarding employing and managing people in organizations is considered human resource management [5], which is illustrated in the following section.

2.1. The management and development of human resources

Human resource management is defined as a strategic approach towards the effective employment and development of a highly committed and qualified workforce to achieve the company's objectives [5, 6]. Since its first introduction in the early 1980s, essential functions of this concept were the deployment of human resources as well as the recruitment, selection, staffing, retention and release of employees [5, 7–10]. Another vital function is the development of employees, often referred to as human resource development [11]. Focusing on all activities concerning the professional education, learning and training of individuals and teams, this function heavily influences the organizational development and thus, the present and future performance of any organization [12, 13].

Hamlin and Stewart [14] conducted an extensive literature review and derived the following main goals for human resource development:

- Improving individual / group effectiveness & performance
- Improving organizational effectiveness & performance
- Developing knowledge, skills & competencies
- Enhancing human potential & personal growth

Thus, the three main functional areas of human resource development can be defined as personal development (competencies), team development (collaboration) and organizational development (structure and processes).

2.2. Strategic competence development

Developing a workforce to meet present and future market needs postulates the identification of required competencies. Competencies are defined as the set of skills, abilities, knowledge, attitudes and motivations an individual needs to cope with job-related tasks and challenges effectively [5, 15]. Most authors identify four main categories to classify competencies. Firstly, technical competencies comprise all job-related knowledge and skills, whereas secondly, methodological competencies include all skills and abilities for general problem solving and decision making. Thirdly, social competencies encompass all skills and abilities as well as the attitude to cooperate and communicate with others. Finally, personal competencies include an individual's social values, motivations, and attitudes [13, 15, 16]. Qualification, on the other hand, is the process of developing the required set of competencies through trainings and education [16].

Competence development and qualification interact as a continuous improvement cycle. While competence development aims to identify required competencies and subsequently helps to reveal critical gaps, the purpose of qualification is to close those gaps. In order to enhance the transparency of this process, a competence model can be used.

3. Development of competence model for Industry 4.0

As described in the methodology, the development of a competence model comprises three vital steps: the identification of emerging challenges (chapter 3.2.), the deduction of competencies to face those challenges (chapter 3.3.&3.4.), and the visualization of required competencies with the help of a suitable instrument (chapter 3.5.).

3.1. Defining Industry 4.0

As a part of the recent high-tech strategy of the German government, the term Industry 4.0 is often referred to as the fourth industrial revolution [17]. The concept of Industry 4.0 describes the increasing digitization of the entire value chain and the resulting interconnection of people, objects and systems through real time data exchange [3, 18]. As a result of that interconnection, products, machines and processes are equipped with artificial intelligence and get enabled to adapt to spontaneous changes of the environment independently. Furthermore, smart objects become embedded in broader systems, which enhance the creation of flexible, self-controlling production systems. There are various fields of application for smart objects and systems, however, the main focus still lies on industrial applications [19, 20].

3.2. Identification of emerging challenges in Industry 4.0

Absolutely, Industry 4.0 creates many new opportunities for companies, but at the same time several challenges arising from the ongoing automation and digitization. In the following chapters, macro-environmental challenges are being analyzed using the PESTEL-framework considering political, economic, social, technical, environmental, and legal factors.

Economic challenges: With an ongoing globalization process, companies have to cope with reduced time-to-market, shorter product lifecycles, and the need to cut costs in order to stay competitive [1–3]. While classical business models become easily vulnerable to substitutes, companies need to streamline their innovation processes and transform their business model to a higher level of service orientation [21]. In addition, customer expectations have shifted towards a higher level of customization and flexibility. As a result, markets have become increasingly volatile and heterogeneous [2–4]. Subsequently, the need for collaboration is more existent than before. Companies now have to enter strategic alliances with their suppliers or competitors to stay competitive. That further leads to the correlation of entire value chains, and as a consequence, increases the complexity of processes [2, 3, 22].

Social challenges: One of the most influencing social challenges is the demographic change. Less young people are entering the labor market to replace those retiring [4]. Thus, strategies need to be developed to attract young people, whilst retaining the knowledge from older employees. Moreover, younger generations express contrary social values, such as the growing importance of a good work-life balance [4]. That goes in hand with the growing employee flexibility due to changes in work organizations. However, boundaries need to be set up to restrict the continuous availability of employees, so that their work life does not interfere with their private life [1, 3]. Increasing virtual work and flexible work topics also require new forms of lifelong learning [22, 23]. Additionally, processes are becoming more complex, which leads to an increase of jobs with higher qualifications and a loss in jobs requiring lower qualifications [3, 22]. Therefore, companies need to qualify their employees for more strategic, coordinating and creative tasks with higher responsibilities.

Technical challenges: As an result of an exponential growth of technologies companies must be able to efficiently deal with a huge amount of data (big data) [20]. Thus, extensive IT infrastructures, like communications networks and internet protocols, need to be built and implemented [22, 24]. To ensure the unproblematic exchange of data between partners within a network, it is further necessary to develop standardized interfaces and open architectures, which enables collaborative work together on different platforms [18, 22, 24]. The storage of large amounts of data on external servers raises the additional problem of cyber security, as data must be protected from unauthorized access [18, 20, 21, 24]. Employees must further acquire the skills to be prepared for the increase in virtual work, e.g. with virtual glasses [1, 4].

Environmental challenges: One main challenge concerning the environment is the ongoing climate change [4]. Conditions in biospheres continuously change, which has an impact on all living organisms within the system. In addition, the efficient utilization of natural resources becomes more critical, considering most of them are scarce. As a result, companies recognize their role in driving sustainable solutions [3, 4].

Political and legal challenges: The most evident political challenge is the increasing need for funding of research programs [22]. Governments need to support organizations with the development of new technologies as well as the integration of those technologies in the existing environment. Moreover, governments need to establish legal parameters for the usage of big data. The most important concern is the protection of privacy, because data will be collected on everything while interacting with smart objects [22, 24]. Growing work flexibility further requires the establishment of regulations for work times and safety to protect employees.

3.3. Deriving competencies from identified challenges

This chapter shows the logical deduction of required core competencies for employees in Industry 4.0. On that account, major emerging challenges were first analyzed for their needs. Following that, possible competencies were derived, which are presented for each challenge in the following table.

Table 1: Derivation of core competencies for identified challenges

Economic challenges	*Ongoing globalization* Intercultural skills, language skills, time flexibility, networking skills, process understanding
	Increasing need for innovation Entrepreneurial thinking, creativity, problem solving, work under pressure, state-of-the-art knowledge, technical skills, research skills, process understanding
	Demand for higher service-orientation Conflict solving, communication skills, ability to be compromising , networking skills
	Growing need for cooperative and collaborative work Ability to be compromising and cooperative, ability to work in a team, communication skills, networking skills
Social challenges	*Demographic change and changing social values* Ability to transfer knowledge, accepting work-task rotation and work related change (ambiguity tolerance), time and place flexibility, leadership skills
	Increasing virtual work Time and place flexibility, technology skills, media skills, understanding IT security
	Growing complexity of processes Technical skills, process understanding, motivation to learn, ambiguity tolerance, decision making, problem solving, analytical skills
Technical challenges	*Exponential growth of technology and data usage* Technical skills, analytical skills, efficiency in working with data, coding skills, understanding IT security, compliance
	Growing collaborative work on platforms Ability to work in teams, virtual communication skills, media skills, understanding of IT security, ability to be cooperative
Environm. challenges	*Climate change & resource scarcity* Sustainable mindset, motivation to protect the environment, creativity to develop new sustainable solutions
Political and legal challenges	*Standardization* Technical skills, coding skills, process understanding
	Data security & personal privacy Understanding of IT security, compliance

3.4. Aggregation and categorization of competencies

According to Leinweber [25] it is essential to cluster the identified competencies into predefined groups to ensure the further clarity and transparency of the model. Therefore, an aggregation of the previously defined competence list is required to remove potential duplications. The next step comprises the clustering of competencies into the four identified main categories of competencies. This assignment of identified competencies into categories is depicted in Table 2. Furthermore, the most referred to studies on competencies for future work were analyzed as part of a comparative study. This comparative study was conducted for the purpose of confirming the importance of the deducted competencies for Industry 4.0. References that emphasize the prospective significance of each competence are shown below.

Table 2: Set of aggregated competencies by their categories

Category	Required competencies	Context	Comparative references
Technical competencies	State-of-the-art knowledge	Due to increasing job responsibility knowledge is getting increasingly important	[26, 27]
	Technical skills	Comprehensive technical skills are needed to switch from operational to more strategic tasks	[26, 28]
	Process understanding	Higher process complexity demands a broader and deeper process understanding	[27, 29, 30]
	Media skills	Increasing virtual work requires employees to be able to use smart media, e.g. smart glasses	[26, 28, 31]
	Coding skills	Growth of digitized processes creates a higher need for employees with coding skills	[26, 31, 32]
	Understanding IT security	Virtual work on servers or platforms obligates employees to be aware of cyber security	[27, 30, 31]
Methodological competencies	Creativity	Need for more innovative products, as well as for internal improvements, requires creativity	[26, 31, 32]
	Entrepreneurial thinking	Every employee with more responsible and strategic tasks has to act as an entrepreneur	[26, 31, 33]
	Problem solving	Employees must be able to identify sources of errors and be able to improve processes	[26, 28, 31]
	Conflict solving	A higher service-orientation increases customer relationships; conflicts need to be solved	[26]
	Decision making	Since employees will own higher process responsibility, they have to make their own decisions	[26, 28, 31]
	Analytical skills	Structuring and examining large amounts of data and complex processes becomes mandatory	[26, 31, 33]
	Research skills	Need to be able to use reliable sources for continuous learning in changing environments	[31]
	Efficiency orientation	Complex problems need to be solved more efficiently, e.g. analyzing growing amounts of data	[29, 33]
Social competencies	Intercultural skills	Understanding different cultures, especially divergent work habits, when working globally	[28, 32]
	Language skills	Being able to understand and communicate with global partners and customers	[32]
	Communication skills	Service-orientation demands good listening and presentation skills, whereas increasing virtual work requires sufficient virtual communication skills	[26, 32, 33]
	Networking skills	Working in a highly globalized and intertwined value chain requires the knowledge networks	[26, 31]
	Ability to work in a team	Growing team work and shared work on platforms expects the ability to follow team rules	[26, 30, 31]
	Ability to be compromising and cooperative	Entities along a value chain develop to equal partners; every project needs to create win-win situations, especially in businesses with increasing project work	[26, 31]
	Ability to transfer knowledge	Companies need to retain knowledge within the company; especially with the current demographic change, explicit and tacit knowledge needs to be exchanged	[26, 30, 31]
	Leadership skills	More responsible tasks and flattened hierarchies make every employee becoming a leader	[27]
Personal competencies	Flexibility	Increasing virtual work makes employees become time and place independent; work-task rotation further requires employees to be flexible with their job responsibilities	[26, 31–33]
	Ambiguity tolerance	Accepting change, especially work related change due to work-task rotation or reorientations	[26, 30, 33]
	Motivation to learn	More frequent work related change makes it mandatory for employees to be willing to learn	[30, 33]
	Ability to work under pressure	Employees involved in innovation processes need to cope with increased pressure, due to shorter product life cycles and reduced time-to-markets	[31]
	Sustainable mindset	As representatives of their companies, employees also need to support sustainability initiatives	[26]
	Compliance	Stricter rules for IT security, working with machine, or working hours	[31, 32]

3.5. Visualization of identified core competencies

After having all required competencies identified, aggregated and categorized, the competence model solely needs to be visualized. This final step will further increase the transparency to understand competence requirements and helps the user to detect competence gaps at first sight.

The visualization is based on the concept of radar charts, which are used to display multivariate data in a two-dimensional chart. Due to those characteristics they are commonly used for gap analyses and, thus, a convenient instrument to visualize a competence model. In order to visualize competence gaps, radar charts need to comprise the following components: required competencies, a scale, and a required scale value for each competence. In addition to those components, the actual measured value will also be illustrated in the radar chart. That further allows the measurement of the gap between required and measured competence levels.

Since the most important competencies for Industry 4.0 were already identified, a scale needs to be defined in the next step. A widely used scale for competence level measurement consists of five levels from nonexistence up to an outstanding peculiarity (one to five) of a competence. The establishment of required competence levels is varying for every job role and therefore needs to be performed when the model is actually in use (see chapter 4.1.).

The distinctiveness of the visualization used for this competence model is the aggregation of several radar charts

into one composed radar chart, which is shown in Figure 2. Therefore, one radar chart got created for every competence category. Those single radar charts further got combined into one aggregated radar chart. This style of visualization enables its viewer to recognize general gaps at the competence category level and further allows an analysis at individual competence level. The scale of the inner radar chart measuring competence categories works on the basis of percentages. By comparing the sum of measured competence level values for a category to the sum of highest possible values, the percentage value gives an average of how qualified an employee is in an entire competence category.

Figure 2 shows the visualized competence model including an exemplary employee evaluation. Competencies are clustered around their categories and the red area symbolizes the minimum required competence level for each competence. The green area indicates the actual competence level the evaluated employee has. Thus, if the red area is visible at any point that would reveal a competence gap required to get closed with the help of a suitable qualification strategy.

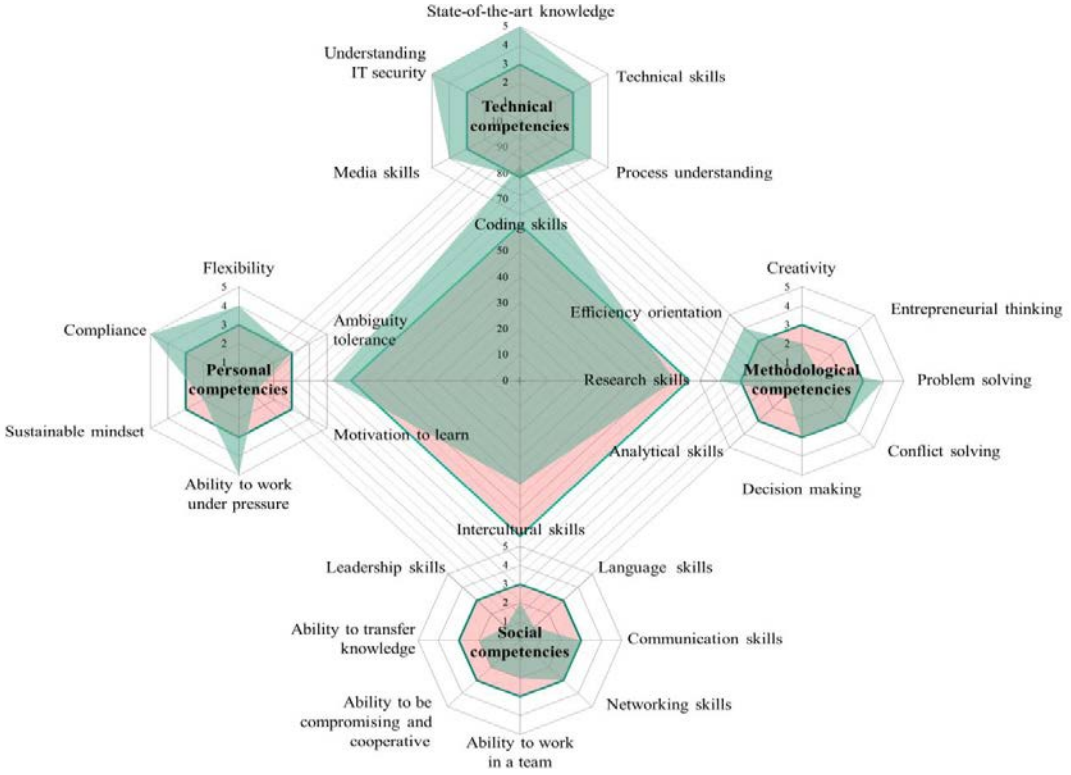

Figure 2: Visualized competence model

4. Potential use of the developed competence model

The purpose of this chapter is to illustrate how the developed competence model can be used in practice. This is of special importance for the Fraunhofer Institute for Production Systems and Design Technology, since the competence model shall be tested and used in a mutual research project with a union of small and medium-sized enterprises.

4.1. Using the model for an employee readiness analysis

Generally, the developed model enables companies to conduct a competence gap analysis for required competencies in Industry 4.0. The tool is designed to assess individual employees, since the given competencies are too specific to generalize them on an entire workforce. Furthermore, it needs to be considered that the assessment of employees should be conducted by an experienced person to minimize biases and to obtain consistent results.

Firstly, the model's competencies need to be weighted accordingly to the department or job profile of the employee to be assessed. As stated earlier, the model shows the most important competencies for Industry 4.0, however, every job profile requires slightly different advancement levels for each competence. Thus, the required scale value for every individual competence needs to be adjusted.

Secondly, the assessment of the employee can be initiated. Therefore, an expert should make use of standardized competence assessment, e.g. through surveys or monitoring activities. Results further need to be compiled and transferred into the competence model.

Having all requirements defined and all competencies of an employee evaluated, the model will reveal all existing competence gaps. That shows the readiness of an employee for his job in Industry 4.0. Furthermore, it is possible to

identify the most critical gaps at first sight. Those are the competencies human resource development needs to focus on.

For example, as it is shown in the exemplary visualization of the competence model in Figure 2, social competencies are not sufficiently developed. Analyzing the individual competencies of that category it is obvious that almost none of the competencies reach the required level. Furthermore, the aggregated radar chart shows that leadership and language skills are being the least developed competencies and demand need for action.

4.2. Defining tailored qualification strategies

In order to fill previously identified gaps, qualification strategies need to be developed. Focus should first be put on the largest competence gaps, since those determine the largest weak spots for an employee to cope with challenges in Industry 4.0. Ordinarily, qualification strategies comprise different methods and techniques, such as trainings and education, to build up specific competencies. Therefore, a company must define actions in advance of using this model that will be triggered once an employee does not reach the required scale level for a competence. Following this reasoning, the competence model could immediately present suitable trainings for an employee.

5. Conclusion and outlook

In the first part of this contribution, a comprehensive list of essential competencies for the work in a digitized and interconnected world was compiled. Even though every job has different requirements, the identified competencies are becoming progressively important and need to be addressed by human resource development. In addition, all identified competencies got visualized in an aggregated radar chart, which helps the user to easily understand imposed requirements on individual competencies. The second part of this paper briefly discussed a general application strategy for the competence model. It was shown how the model can be used to assess and develop an employee's competencies to overcome future challenges.

Further research should focus on the development of specific job profiles, as well as on the integration of individual qualification methods for the in the competence model utilized competencies. The will enhance the speed and agility of closing competence gaps with the help of the model.

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