A Competency Model for "Industrie 4.0" Employees

Loina Prifti[1], Marlene Knigge[1], Harald Kienegger[1], and Helmut Krcmar[1]

[1] Technical University Munich, Chair of Information Systems, Munich, Germany
{prifti,marlene.knigge,harald.kienegger,krcmar}@in.tum.de

Abstract. This paper analyzes employee competencies for employees with higher education in Industry 4.0. An Industry 4.0 competency model based on a behavioral oriented approach concerning three variants, namely Information Systems, Information Technology and Engineering is developed by extending the SHL Universal Competency Framework through a structured literature review and focus groups with academic staff. The presented study contributes to research by providing a starting-point for further research regarding employee competencies for Industry 4.0. It contributes to practice as the provided competency model can be applied to Industry 4.0 job descriptions.

Keywords: Digital Transformation, Industry 4.0, Internet of Things, Competency, Competency Model.

1 Introduction

Recent technological developments, such as sensors, cyber-physical systems, the Internet of Things (IoT), or smart networks will influence each area of our life. This development is referred to as the fourth industrial revolution, also known as "Industrie 4.0" or "Industry 4.0" (I4.0). I4.0 is widely used in the international context, however we focus on the German concept of I4.0. In this context it approaches some of the challenges the world is facing today including the rise of resource and energy efficiency, production, demographic change etc. [1]. Further, it offers a huge potential especially for Germany as a global leader in the manufacturing industry [1]. Germany also possesses significant information technology (IT) know-how and competencies in automation, embedded systems or smart networks [1]. This offers the perfect prerequisites for Germany to become a leader in I4.0. "In essence, I4.0 will involve the technical integration of cyber-physical systems into manufacturing and logistics and the use of the Internet of Things and Services in industrial processes." [1]

I4.0 will influence our working environments significantly. E.g., it will change processes in purchase, production, manufacturing, sales or maintenance by including concepts as smart manufacturing, smart maintenance as well as a high degree of automation and integration in all enterprise processes [2]. It will have far-reaching implications on business value creation, business models, downstream services, and work organization [1]. As a consequence, employees will be confronted with transformed work processes and business models as well as with new technologies [2]. The model of work organization will transform due to the disruptive nature of emerging

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technologies and modified structures for communication and collaboration [3]. Processes will become interconnected and more complex. The technical, organizational and social spheres of work activities will overlap. The way we work will be one of the most affected changes in I4.0 [4]. I4.0 will not only affect technology and production, but the way we will work in all its dimensions [5].

This transformation of the work environment will change the job profiles and therefore requires employees to be outfitted with a wide range of competencies [1, 2, 6]. In I4.0, work profiles that require a higher education will gain increasing significance, while labour workforce will be mostly replaced by automated processes [1]. As a consequence, various practitioners and researchers agree that the competency development for students and employees applying for jobs that require higher education, is one of the key challenges to adapt I4.0 [3, 7-12]. To address this challenge, Erol, Jäger, Hold and Sihn [9] propose competencies derived from the literature by offering a scenario-based learning concept for students. acatech, Fraunhofer Institut für Materialfluss und Logistik and equeo GmbH [2] analyzed German companies by following a holistic approach and propose a set of competencies divided in two areas: competencies that the companies should master and competencies that the employees should adapt. Other authors also analyze working in I4.0 by specifying competencies that will become important [4, 7, 13-15].

In order to successfully get through the transformation towards I4.0, a clear definition of the competencies for I4.0 is needed [7, 8, 16]. Furthermore, a clear description of the relationship and connection between these competencies can provide the foundation for competency development in the future [2]. The best way to address this point would be a structured competency model, which addresses I4.0 competencies for graduates. I4.0 is accompanied by the enhancement of production machines, which requires adjusted competency profiles for engineers. IT assumes the role of programming these machines and designing adjusted IT architectures, which requires new competencies for IT professionals. These changes in production, the transformation of business processes as well as new ways of communication and collaboration will lead to adjusted or even new IT processes and structures, but also to a different way of managing people, which requires customized competency profiles for Information System (IS) professionals. Job profiles for engineering, IT, and IS employees need to be adjusted and include new competencies in order to cope with I4.0.

Therefore, we address this research gap by identifying competencies for I4.0. We focus on three areas that require higher education and will be of high relevance in I4.0: IS, IT, and Engineering. Our research addressed the following research question:

RQ: What competencies are critical for job positions that require higher education for effectively and efficiently performing in I4.0?

We offer a competency model with three different variants for these three areas by combining two research methods: a literature review and focus groups.

In the next section of this paper we describe the main concepts used throughout this research: “Competency”, “Competency Model” and “Industry 4.0”. Afterwards we explain the applied methodology by describing in detail each of the applied research methods namely the literature review and the focus groups. In the following section we

present the result of the research by describing the results delivered by each of the methods and the delivered competency model. We conclude the paper with a discussion of our findings.

2 Background

2.1 Competencies

Many disciplines of research, such as Psychology, Education, Organizational Management, Human Resources or Information Systems have studied the concept of competencies. Various researchers provided different definitions over the years and caused a debate that is still ongoing [17]. The first definition of competencies was delivered by McClelland [18], who defined a competency as "a personal trait or set of habits that leads to more effective or superior job performance". On later years further definitions can be found in research, e.g., Klemp [19] defined a competency as "an underlying characteristic of a person, which results in effective and/or superior performance on the job". With regards to Spencer and Spencer [20], "competencies are skills and abilities; things you can do; acquired through work experience, life experience, study or training". Bartram, Robertson and Callinan [21] state that competencies are "sets of behaviors that are instrumental in the delivery of desired results or outcomes".

Research on competencies has mainly followed three approaches that were developed independently [17]. The behavioral approach, focuses on attributes which go beyond the cognitive ability, like self-awareness, self-regulation and social skills [18, 22]. This approach argues that competencies are fundamentally behavioral unlike personality or intelligence and can be taught through learning and development. The functional approach focuses on competencies as requirements for successfully fulfilling a task by restricting the term of competencies to the skills and know-how required for conducting a task [23, 24]. The holistic/multi-dimensional approach describes competencies as a collection of individual competencies required from an individual – and organizational competencies required on the organization level to achieve the desired results [25].

In this study we focus on the individual as a key factor in I4.0, by analyzing the broad spectrum of competencies for individuals not only on functional but also on behavioral level. We do not define a list of skills for fulfilling a certain task and also do not address organizational competencies. Moreover we want to offer an overview of the competencies that should be taught to individuals for successfully working in I4.0. Therefore we apply the behavioral-based approach since it offers the best fit for our purpose, by giving also the possibility to describe the relationship between competencies as constructs on the one hand, and psychological constructs such as motives and personality traits on the other [26].

For the purpose of this study we use the definition of Bartram, who defines competencies as: "sets of behaviors that are instrumental in the delivery of desired results or outcomes" [21]. In this sense "a competency is not the behavior or

performance itself but the repertoire of capabilities, activities, processes and responses available that enable a range of work demands to be met more effectively by some people than by others" [27].

2.2 Competency Models

A competency model consists of desired competencies for a certain task and may also include a description of single competencies [28-30] as well as indicators to measure performance and outcome. This lists may include different detail levels and also describe relationships between the competencies.

Many competency models have been developed over the years. E.g., Erpenbeck and Rosenstiel [31] offer a model by separating the competencies into four categories: personal, social/interpersonal, action-related and domain-related competencies. Egeling and Nippa [32] use another classification by separating competencies in meta, domain, method and social competencies. Other authors offer competency models for leadership and management [22, 24, 33]. There are also competency models for certain tasks or job profiles [26, 32].

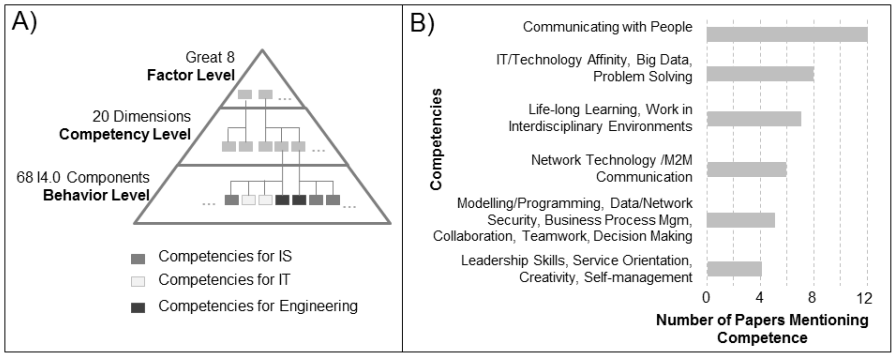

Fig 1. A) Industry 4.0 Competency Model Structure (Source: Own representation with regards to [37]); **B)** Most Mentioned Competencies in the Literature (Source: Own representation)

CEB Inc. [34][1] offers the SHL Universal Competency Framework (UCF)[2] [35] as a generic foundation for building competency models. This behavioral-based framework was derived by analyzing practitioners and academic approaches. It consists of three hierarchical levels, with the first level called "Great Eight". It describes the eight core factors that underpin job performance. All competencies can be clustered in these eight groups of competencies, followed by 20 competency dimensions that divide these eight groups in further categories, which are separated into 112 component competencies. At this level all available competencies are described and each competency can be matched

1 CEB Inc. is a global best practice and insights technology company providing services to businesses worldwide [34].

2 SHL Universal Competency Framework (UCF) presents a state-of-the-art perspective on competencies and is used worldwide from well-known companies as e.g. Coca Cola [36]. It is offered by CEB Inc (see above) [35].

at one of the 112 elements (Fig. 1A). Moreover, it offers a deep level of detail. This framework offers a general perspective on competencies, within which competency models for concrete topics can be developed. For our model we adapted the competency framework (see Fig. 1A) by using the "Great Eight" as the first level and the 20 competency dimensions as the second level. We adapted the needed competencies of the behavior level as third level based on our results from the literature and focus groups. This way we based our model on a well-known framework from practice and research and adapt this framework for the I4.0 needs.

Choosing this existing framework offers many advantages. It offers a state of the art structure for competency modeling by not only listing the competencies but also showing the relationships between them. The framework is used both in research and practice, so our work makes a two-fold contribution. Since many companies apply it to build their competency profile, it offers the potential to compare our results with industry profiles in practice.

2.3 Industry 4.0

I4.0, also known as the fourth revolution, is one of the ten future projects of the High-Tech-Strategy 2020 action plan that was announced the first time by the Federal Government at the „Hannover-Messe" in 2011[1]. Its aim is a more efficient, flexible and individual production, achieved through decentralized controls of production and completely digitally controlled or even self-organized value chains [4], and where automation, real-time and sensor technologies play a crucial role [1]. "Plattform Industrie 4.0"[38] defines I4.0 as:

„[...] the fourth industrial revolution, the next stage in the organization and control of the entire value stream along the life cycle of a product. [...] based on increasingly individualized customer wishes and ranges from the idea, the order, development, production, and delivery to the end customer through to recycling and related services. [...] availability of all relevant information in real-time through the networking of all instances involved in value creation as well as the ability to derive the best possible value stream from data at all times. Connecting people, objects and systems leads to the creation of dynamic, self-organized, cross-organizational, real-time optimized value networks, which can be optimized according to a range of criteria such as costs, availability and consumption of resources."

It should be noted that the term I4.0 is widespread in German speaking countries. However, similar concepts and visions are often used under another term in the international context. For instance, I4.0 is known by the term „industrie du futur" in France, or the „Industrial Internet"[39] as well as further similar concepts as „Internet of Things", „Internet of Everything" „Smart Factory" or "Digital Transformation" in the international context [40, 41]. All this concepts include the use of automation, real-time, sensors and further modern technologies to transform business processes and therefore achieve a business value, however they slightly differ from one another in various aspects. For the purpose of this study we refer to I4.0 as a German concept with regards to the definition presented above.

3 Methodology

3.1 Literature Review

To define competencies for I4.0 we conducted a systematic literature review, which offers a rigorous view of research results [42]. We chose a concept-centric approach by following the recommendations of Webster and Watson [43]. The main objective of the literature review was to identify, classify and summarize competencies about I4.0 that were defined in the literature.

Following the guidelines of Webster and Watson [43] we searched by using the keywords: "Industrie 4.0"; "Industry 4.0"; "Digital Transformation"; "Internet of Things"; "IoT"; "Cyber Physical Systems"; "CPS" and combined each of them with the keywords: "competence", "competency"; "skill"; "knowledge"; "attitude"; "ability"; "value"; "education". Our goal was to conduct an exhaustive literature search and cover the state-of-the art literature about I4.0 competencies. The chosen databases were ACM Digital Library, IEEE, Springer and EbscoHost[3] because they cover publications from the IS, Economics, IT and Engineering discipline, as well as many Education outlets including conferences like EDUCON, REV, ICL, and Frontiers in Education that are often target outlets for publishing competency studies regarding actual topics like I4.0. The search included all articles that were published until August 2016. All the hits were first screened based on the title and abstract. In a second phase, the whole articles were screened. Additionally, a Google Scholar search was conducted in order to discover relevant articles from conferences and journals that were not included in the databases mentioned above. Here, the articles were sorted by relevance and the first 30 hits for each search string were screened. By following the recommendations of Webster and Watson [43], a backward and forward search was also conducted from the analyzed articles. Articles that did not include concrete competencies were excluded from our analysis. We had a total of 3363 hits in the database search, after the first screening 26 articles from the databases remained for further analyzes. Only articles where explicit competencies are mentioned were chosen. At the end a total of 17 that mention competencies for I4.0 or similar concepts such as IoT, were selected for further analysis. One of the articles was from the backward search.

Since the topic is new, only little research exists. However we conducted a literature review to summarize the state of the art before gathering any further data. The topic is of high practical relevance and broadly discussed in practitioners' texts. Therefore by following the recommendations of Levy and Ellis [44], we also considered practical articles, white papers and reports that propose competencies for I4.0. These were determined through Google search and delivered a total of 10 practical articles included in our analysis. Finally, 27 articles including research and practitioners' publications were considered and analyzed.

[3] The used EbscoHost Databases are: Business Source Premier, EconLit, Information Science & Technology Abstracts, Education Source, ERIC, Business Source Complete

From each article we extracted the mentioned competencies and built a concept matrix as proposed by Webster and Watson [43]. If the same competency was covered as a synonym in different papers e.g. “smart data” and “big data” we considered this as one competency and used the more popular term.

3.2 Focus Groups

For evaluating and extending the literature review, we conducted focus group interviews as recommended by Krueger and Casey [45]. A total of four focus groups with 18 - 25 participants each were conducted. The focus groups lasted 45 minutes on average. The participants in the focus groups were lecturers with previous experience in companies or various years of experience in university teaching and education in the areas of IT, IS, Economics and Engineering. This target group was addressed since lecturers have a general understanding of competencies and apply competency targeted teaching. Most of them also are involved in research and therefore are aware of I4.0, its relevance and the importance of building up competencies for the future employees. Three of the focus groups included lecturers from different countries in the EMEA region e.g. Germany, Austria, Netherlands and Egypt. They were conducted at the Technical University of Munich during training workshops for lecturers, who are interested in modern technologies that can be applied for teaching purposes, including topics of digital transformation, IoT and I4.0. The last focus group included professors and lecturers from Germany, Austria and Switzerland. It was conducted during a workshop at a German software company that aimed, among other topics, in discussing challenges and technologies that should be applied in today’s education. Using the setting of a workshop was helpful since each group had already known each other during the workshop and built a certain group dynamic that positively influenced the discussion. The participants also had time to discuss and think about I4.0 related topics during the workshops, so they were in the right mindset for the discussion and for building up ideas. Due to the given group dynamic and workshop setting we decided to limit the focus groups to the given lecturers and professors, since most of them had also practical insights from their previous jobs.

All focus groups have been moderated by the same person, a co-author of the paper. We used the same semi-structured guidelines in each of the focus groups to ensure that the findings are comparable. We applied the Critical Incident Technique [46, 47] for the focus group guidelines in order to derive the competencies for I4.0. The participants were presented with typical work scenarios and products of I4.0. Then questions were asked about the competencies that employees should bring in Engineering, IT and IS to efficiently work in this scenario.

The focus groups were recorded and transcribed. We coded the transcripts using the software MAXQA and combined an inductive with a deductive coding approach. This means we took the competencies from the literature as codes and started coding the transcripts. If a new competency was mentioned in a focus group that was not part of the codes, we used this as a new code meaning a new competency in our list. The coding was conducted twice from two different researchers. The codes were lastly compared and the differences were discussed until a common decision on the code was achieved.

4 Results

4.1 Results from Literature

Based on the literature, a total of 64 competencies could be derived. Most of them were behavioral ones and underline the importance of behavioral competencies for I4.0. It cannot be expected that a single person possesses all the mentioned competencies. So different combinations of the competencies represent specific job profiles for I4.0. The most mentioned competencies and their occurrence in the analyzed literature are presented in Fig. 1B.

Various authors underline that communication is one of the key competencies required from graduates [1, 2, 6, 7, 9, 13, 48-53]. Others go further by putting the communication competency in relation with other competencies like literacy [50] and technical communication [9, 50], intercultural competency [9, 13, 50], or presentation ability [54]. Social skills like collaboration [2, 7, 49, 54, 55], compromising [9], and negotiating [55] combined with emotional intelligence [55] will play a key role in I4.0 since they also play an important aspect in teamwork [7, 9, 48, 49, 51], project management [52, 53], and management ability [6], customer orientation [2, 13], maintaining customer relationships [2, 56], and creating business networks [2, 56]. Work and collaboration will become more complex, therefore I4.0 requires graduates with analyzing competencies like problem solving [2, 4, 6, 7, 9, 15, 49, 55], optimization [2, 4], analytical skills [9, 12, 57], and cognitive abilities [55]. To be able to coordinate these competencies, being able to manage complexity [2, 9] and abstraction ability [6, 9, 15] are crucial. Graduates in I4.0 should bring leading and deciding competencies like decision making [1, 2, 6, 55, 58], taking responsibility [6] and leadership skills [2, 6, 12, 55], which should be combined with a set of principles and values with competencies like respecting ethics [51], environmental awareness [52, 53], and awareness for ergonomics [48].

I4.0 will lead to a dynamic, international and interdisciplinary work environments, therefore competencies such as working in interdisciplinary environments [2, 4, 7, 12, 48, 51, 54], flexibility [9], adaptability [48, 49] as well as innovating [2, 14], creativity [7, 9, 14, 49], critical thinking [49], and change management [56] gain a new importance. For being able to always adapt the latest technologies and make the most out of them, graduates should apply life-long learning [4, 9, 12, 49, 50, 51, 54] and knowledge management [48, 49] while being focused on business strategy [3], always changing business models [3, 54] and entrepreneurship [49]. The work environment will become very demanding, so a graduate will need to find work-life balance [9] and needs to have the competency of self-management and organization [1, 6, 48, 49] as well as of planning and organizing work [13, 49, 57]. Nevertheless he should bring legislation [48, 52, 53] and safety awareness [51, 57] as well as individual responsibility [6].

Apart from all the behavioral competencies mentioned above, graduates must also bring domain related competencies as well as the ability to apply expertise and use technology. In this area all graduates need to bring IT and technology affinity [2, 4, 9, 12, 13, 48, 56, 57], economics knowledge [52, 53], and be able to extract business value

from the use of social media [9, 56]. IS graduates should have knowledge in service orientation and product service offerings [2, 3, 56, 59], business process [2, 3, 9, 48, 54], and change management [56]. IT graduates should have knowledge of digital security, including data and network [2, 3, 51, 56, 59], and while working with engineers both groups should bring the competency of integrating heterogeneous technologies [51-53], knowledge about mobile technologies [56] and embedded systems and sensors [51], knowing network technology and M2M communication [2-4, 9, 54, 59] as well as possess knowledge of robotics and artificial intelligence [2, 12, 57]. On the other hand, IT and IS graduates should both bring modelling and programming knowledge [9, 12, 48, 58, 60], knowledge about cloud computing and cloud architectures [2, 56, 59], in-memory DB knowledge [56] and statistics [48]. For both groups, big data and data analysis and interpretation [2, 3, 9, 12, 48, 54, 56, 61] will be of big importance.

4.2 Focus Group Results

The most mentioned competency in the focus groups was big data/data analytics competency. "*I think it is about all different kind of data, also geo data but also video data, images, all ERP data, structured data and unstructured data like Facebook etc." "So to use anonymized big data and volume data and data traffic to predict macro business events rather than micro."* The participants see this as the next big thing and believe that for succeeding in I4.0, a combination of big data competency with sensors and mobile technology as well as predictive maintenance and machine learning will be very important.

The next most mentioned competency is process know-how and process management competency. De facto, processes are in the focus of I4.0, with automation playing an important role. The participants also underlined that business model understanding and entrepreneurship will play a special role in I4.0 since this will transform business models. The employees of tomorrow should be prepared to use the technological advances as an advantage and adapt in a fast changing world. "*The question is: Which potential does the digitalization bring and which new services can be offered based on that?*"

The participants also stressed that interdisciplinary competency will play a new role in I4.0. An engineer will have to collaborate with the IS and IT specialists in order to achieve results in the interconnected environment that we will face.

The domain or analytical oriented competencies like IT and technology affinity, network administration, data security cloud architectures, programming, in-memory DBs were also important in the discussion. *"Just to have the picture. You run through the world and Industry 4.0, you know there are so much sensors." "The more technical people they should know afterwards how to create systems."*

Lastly the participants also mentioned further behavioral competencies like customer orientation, decision making, communication, innovating, legal, ethics, and teamwork. *"I do not need to understand the whole technical background, but I need to be able to make decisions." "…we should offer group work, so that the participants learn to communicate and work in teams"*.

Compared to the literature we could add four new competencies that were mentioned in the focus groups but have not been found in literature, as customer relationship management, IT architectures, machine learning, and predictive maintenance. Competencies in the dimension of leading, like leadership skills, or persuading and influencing like negotiating and emotional intelligence that were often mentioned and analyzed in the literature have not been mentioned at all during the focus groups. The mentioned competencies were generally more abstract, lacking high detail compared to the literature.

4.3 Developing the Model

The SHL UCF[2] developed by CEB Inc.[1] is based on different competency approaches from research and practice [35]. It offers a behavioral approach for competency modeling by focusing on the individual and considering competencies of behavioral nature, meaning an individual can learn and adopt them unlike, e.g., personality. As a framework it offers a structure and overview of the competencies, by fitting them into descriptive categories [62]. This framework can be used to develop competency models, which represent a descriptive and simplified view of the competencies as a specific phenomenon to be analyzed [62]. The SHL UCF is widely used in practice and many companies use it to describe their competency models for specific job positions [26].

As described earlier, the SHL UCF is composed of three hierarchical levels: the "Great Eight", the competency dimensions and the competency components. We kept the structure and the relationship between the elements and adapted the third level competencies based on the results of our research. The framework delivers 112 single competencies. For I4.0, we considered 68 competencies (Fig. 1A) as relevant. Based on the results of the literature review and focus groups we expanded some of the single competencies or adapted their formulation to serve our purpose. For each of the competencies we did a clustering whether it is relevant for IS, IT or Engineering graduates or whether it can be considered as an interdisciplinary competence for two of the mentioned areas or all three of them. The process of clustering was conducted separately from two researchers and then compared to each other. In case of disagreement the clustering was discussed until achieving a consensus.

The results show that most of the behavioral competencies should be adapted by all three groups of graduates. These competencies are marked in light grey color eg. *Decision Making* or *Teamwork*. It means that the employees of the future, independently from their position should bring a high level of behavioral competencies to successfully work in I4.0. Only competencies under the dimension "Applying Expertize and Technology" have three variants. This dimension of competencies represents domain knowledge, therefore depending on the domain the employees should bring different competencies. Some competencies in this dimension are also categorized to two or more groups of graduates. E.g., *Predictive Maintenance* will be a competency for IT as well as for Engineering graduates, whereas *Big Data* will be a needed competency not only for IS but also for IT graduates. Economics graduates, who follow a technical oriented carrier path, will adapt similar competencies as the IS

Big Eight	*Competency Dimensions*	*Competencies*		
		Information Systems (IS)	Computer Science	Engineering
Leading & Deciding	*Deciding and Initiating Action*	• Decision Making • Taking Responsibility		
	Leading and Supervising	• Leadership Skills		
Supporting and Cooperating	*Working with People*	• Teamwork • Collaborating with Others • Communicating with People		
	Adhering to Principles and Values	• Respecting Ethics • Environmental Awareness • Awareness for Ergonomics		
Interacting and Presenting	*Relating and Networking*	• Compromising • Creating Business Networks • Maintaining Customer Relationships		
	Persuading and Influencing	• Negotiating • Emotional Intelligence		
	Presenting and Communicating Information	• Presentation and Communication Ability		
Analyzing and Interpreting	*Writing and Reporting*	• Targeted/Technical Communication • Literacy		
	Applying Expertise and Technology	• IT and Technology Affinity • Economics • Extract Business Value from Social Media		
		• Service Orientation/ Product Service Offerings • Business Process Management • Business Change Management • Understand and Coordinate Workflows	• Network Security • IT Architectures • Machine Learning	
			• System Development • Integrating Heterogeneous Technologies • Mobile Technologies • Sensors/Embedded Systems • Network Technology /M2M Communication • Robotics/Artificial Intelligence • Predictive Maintenance	
		• Modelling and Programming • Big Data/Data Analysis and Interpretation • Cloud Computing /Architectures • In-Memory DBs • Statistics • Data Security		
	Analyzing	• Problem Solving • Optimization • Analytical Skills • Cognitive Ability		
Creating and Conceptualizing	*Learning and Researching*	• Life-long Learning • Knowledge Management		
	Creating and Innovating	• Innovating • Creativity • Critical Thinking • Change Management		
	Formulating Strategies and Concepts	• Business Strategy • Abstraction Ability • Managing Complexity		
Organizing and Executing	*Planning and Organizing*	• Project Management • Planning and Organizing Work • Management Ability		
	Delivering Results and Meeting Customer Expectations	• Customer Orientation • Customer Relationship Management		
	Following Instructions and Procedures	• Legislation Awareness • Safety Awareness • Individual Responsibility		

Big Eight	*Competency Dimensions*	*Competencies*		
		IS/Economics	IT/Computer Science	Engineering
Adapting and Coping	*Adapting and Responding to Change*	• Work in Interdisciplinary Environments • Intercultural Competency • Flexibility • Adaptability and Ability to Change Mind-set		
	Persuading and Influencing	• Work-Life Balance		
Enterprising and Performing	*Achieving Personal Work Goals and Objectives*	• Self-management and -organization		
	Entrepreneurial and Commercial Thinking	• Business Model Understanding • Entrepreneurship		

Fig 2: "Industrie 4.0" Competency Model (Source: Own representation with regards to [35])

graduates, since these disciplines have similarities. This shows again that the work in I4.0 will be interconnected. Therefore, competencies such as interdisciplinary working, collaboration, communication or teamwork will have a special role.

Our model is presented in Fig. 2. For each of the employee groups you can follow the path and gather all the competencies that should be fulfilled by this group. It cannot be expected that one employee of a certain group masters all the competencies. Therefore, a combination of the competencies, depending on the position will deliver different job profiles for I4.0. E.g. a competency profile for a data scientist responsible for extracting, modeling and visualizing the data produced by a certain sensor in I4.0 can be defined by extracting concrete competencies from the area of IS such as *Taking Responsibility*, *Big Data Analytics and Interpretation*, *Analytical Skills*, *Cognitive Ability*, *Creativity*, and *Critical Thinking*. By following this schema different profiles for different jobs could be defined.

5 Discussion and Limitations

In our research we used the SHL UCF [35] to develop an I4.0 competency model. Most of the defined competencies are not new, however the presented specific combination of competencies for I4.0 is new and makes a contribution to research. Overall, our research emphasizes the importance of employee competencies to successfully get through the transformation towards I4.0. The results of the literature review and the focus group discussions delivered mostly behavioral competencies and only a small part of the competencies represented domain related knowledge. This is also a new aspect with regards to competency building and underlines the changes that I4.0 will bring to the way we work. Job vacancies in today's economy often focus on a list of domain knowledge and comprise only some very generic behavioral competencies, like teamwork or independently working. The same situation is presented if we analyze university lectures and curricula. Their focus often is on teaching the students' domain knowledge. The training of further competencies still often is limited to teamwork situations or presentations to be held. These examples show that domain knowledge are the focus of today's economy, while I4.0 will turn around the work environment. Behavioral competencies will be the most important

competencies that employees should bring. Therefore, research should focus on analyzing how the competency profile of today's employees as well as of students could be adapted for I4.0. This could include the definition of requirements for curricula and training programs for I4.0. Conceptualizing and defining learning strategies and curricula for I4.0 might be another interesting topic for research.

If we consider today's economy and disciplines, there is a clear separation between the competencies that employees from different disciplines should bring. If, for instance, we mention IT, everyone recalls a certain job profile and competency set in their mind that is completely different from the profile that one would recall if we mentioned IS or Engineering. Our study reveals that in the future the competency sets that different disciplines should bring will be very similar and will differentiate only in some aspects of domain knowledge. This would be a further point where research could offer teaching methods for interdisciplinary teaching.

Our literature review also showed that research on I4.0 competencies is rather scarce. The analyzed works mostly underline that the work environment will change, however no concrete vision or competency models were proposed. With our work we make an initial contribution that could be further expanded for other professions that require higher education.

This work has practical implications as well. The proposed competency model could be used in practice by companies and universities. Companies could use the model to define job profiles for I4.0 vacancies. It cannot be expected that one employee will bring all the competencies included in the model, however by combining some of them depending on the position, different profiles can be described. The results can also be used in competency-based curricula designing.

Although there are limitations to our study, we believe that it can serve as a foundation for further research. Our analysis was based on a literature review as well as four focus groups with academic staff. The literature search was limited to the databases, where access by our university, is provided. To complete the results further literature, especially conference proceedings as well as empirical data e.g. focus groups or expert interviews from practitioners would be helpful. We acknowledge that further research in the area of I4.0 competencies is required to study further aspects of competencies as well as define how the model could be applied in practice. Especially a definition of a competency profile for a certain job description, e.g. which competencies of the model should a programmer bring, could be a further interesting point for research and practice.

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