An Intelligent System for Core-Competence Identification for Industry 4.0 Based on Research Results from German and Polish Manufacturing Companies

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Abstract. This article aims to present the concept of an intelligent system for core-competence identification for Industry 4.0, and is based on a survey and data obtained from 62 Polish Manufacturing Enterprises in the Lubuskie region and from 23 German Manufacturing Enterprises from the Brandenburg region - so from 85 manufacturing enterprises in "the region: cross-border cooperation". Special attention is placed on the determination of the weightings of the competencies of employees in the context of the adoption and use of technologies related to Industry 4.0. This is followed by a discussion of the supporting literature and of the results of the empirical studies. Finally, part of an intelligent system for core-competence identification for Industry 4.0 is presented.

Keywords: Core competence · Industry 4.0 · Intelligent system · Manufacturing company

1 Introduction

Human resources are one of three interconnected factors describing the concept of the Fourth Industrial Revolution or Industry 4.0. The term "Industry 4.0" is defined as the resulting interconnection of people, objects and systems through real-time data exchange [4, 13]. This concept includes the vision of digitally enabled production [2]. Thanks to technologies such as the Internet of Things (IoT), the Internet of Services (IoS), the Internet of People (IoP), and the Industrial Internet, Cloud-based Manufacturing, Smart Manufacturing employees' activities within a company and in the company's environment are interconnected. Manufacturing companies operating in Industry 4.0 also need to introduce the challenges to the employees, especially to their competences, arising from the ongoing automation and digitisation.

In this paper, special attention is paid to core-competence model identification for Industry 4.0. The general objective of this research is to develop a general framework for identifying employees' competencies, especially in terms of the determination of the weightings of those employees' competencies in the context of the adoption and use of technologies related to Industry 4.0. So it is very important for them to adequately

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understand the technologies related to Industry-4.0 usage. Based on the definition by Hsieh and Wang [8], the use of technologies by employees in a company is understood as the work by employees in defined technologies, and their work must consist of at least 6 h per day [10].

Therefore, we maintain that an approach for the core-competence model related to the new technologies and processes of Industry 4.0 is needed in manufacturing companies. A competence is an ability to achieve the defined goals [12], and moreover is a set of special skills [7]. According to our previous research [11] we have determined that the competencies of employees to accomplish tasks are often referred to as qualifications and skills. Our motivation to study this approach came from the research results obtained from Polish and German Manufacturing companies. Using survey data from 62 Polish manufacturing companies in the Lubuskie region, and from 23 German manufacturing companies in the Brandenburg region (in the cross-border cooperative region of Lubuskie/Poland-Brandenburg/Germany), this study discusses the competences needed in manufacturing companies in terms of Industry 4.0. The researched companies are in the automotive and construction sectors and constitute 20% of such enterprises in the cross-border cooperative region. This paper develops a core-competence model and shows an implementation of this approach in the form of the author's intelligent system for companies related to Industry 4.0.

Section 2 shows the literature studies related to a competence model for manufacturing companies in Industry 4.0 and presents the main competences of employees based on the research results from German and Polish manufacturing companies. Section 3 develops the authors' core-competence model for Industry 4.0. Finally, Sect. 4 presents a part of an intelligent system for the core-competence identification for Industry 4.0. Section 5 summarises the research results.

2 Core Competences for Industry 4.0

In the literature are defined the core competencies as a set of a combination of organisational, behavioural and technical skills which give an individual the potential to implement the prescribed processes effectively [1, 3, 5].

Hecklaua et al. [6] defined the four main categories of core competencies for employees in Industry 4.0: technical competencies, methodological competencies, social competencies, and personal competencies. They analysed the defined sets of competencies and described the significance of each competence through references. Based on this study, and in order to describe the core competences for Industry 4.0, survey data were collected from 85 manufacturing enterprises in the cross-border cooperative region of Lubuskie/Poland and Brandenburg/Germany, in which the companies were categorised as "construction" or "automotive", or "others". The respondents consisted of managers (over 80%) and chief executive officers, and they were surveyed in the form of direct meetings, email surveys and/or phone surveys. The chosen 85 manufacturing companies from the "automotive" and "construction" sectors contribute about 20% of those enterprises in the cooperative region.

The respondents were asked to evaluate the characteristics of employees in terms of the most important for Industry 4.0. They stated, that they have sufficient knowledge about the assumptions the of the Industry 4.0 idea. Figure 1 presents, based on the research results from the German and Polish manufacturing companies, the most-important characteristics of employees in Industry 4.0. For all kinds of characteristics which were measured, a five-point Likert scale was adopted in which 1 = strongly unimportant and 5 = strongly important.

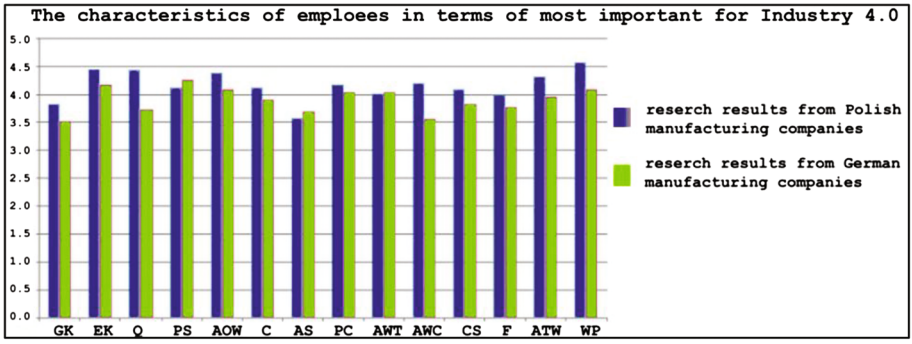

Fig. 1. The most-important characteristics of employees for Industry 4.0. research results from German and Polish manufacturing companies

For a model of core competences for Industry 4.0, fourteen characteristics of employees were identified: general knowledge (GK), expertise knowledge (EK), qualifications (Q), problem solving (PS), the ability to organise work (AOW), creativity (C), analytical skills (AS), personal culture (PC), the ability to work in a team (AWT), the ability to work with customers (AWC), communication skills (CS), flexibility (F), the ability for task-oriented work (ATW), and working under pressure (WP).

Similar results were obtained only for the characteristic *the ability to work in a team (AWT)* in the context of the ability of employees to absorb and use a new technology in Industry 4.0 (average result: 4.02). In other results it can be observed that, for industry 4.0, for the managers of Polish manufacturing companies these characteristics of employees are more important than for the managers of German Companies. Only the characteristic *problem solving (PS*) was scored by managers of German companies as more important than by the managers of the Polish Enterprises.

Based on the study by Hecklaua et al. [6] the following groups of core competences in the context of the ability to absorb and use new technology in Industry 4.0, are defined: Technical Competencies (TC), Methodological Competencies (MC), Social Competencies (SC), and Personal Competencies (PC). The authors defined the following groups of core competences, including the characteristics of employees, in the context of the ability to absorb and use new technology in Industry 4.0, are defined (see Fig. 2):

- Technical competencies (TC): general knowledge (GK), expertise knowledge (EK), (Q) qualifications.

- Methodological competencies (MC): problem solving (PS), the ability to organise work (AOW), creativity (C), analytical skills (AS),
- Social competencies (SC): personal culture (PC), the ability to work in a team (AWT), the ability to work with customers (AWC), communication skills (CS).
- Personal competencies (PC): flexibility (F), the ability for task-oriented work (ATW), working under pressure (WP).

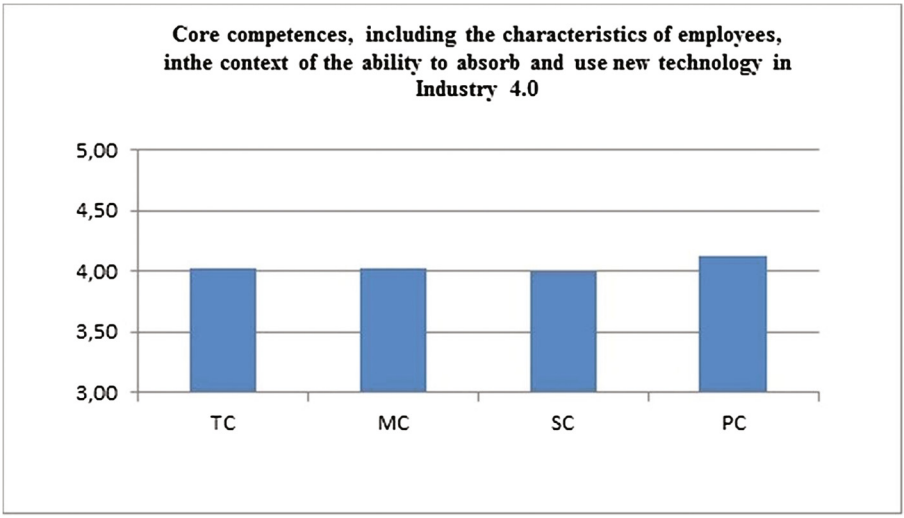

Fig. 2. The core competences, including the characteristics of employees, in the context of the ability to absorb and use new technology in Industry 4.0 - the research results from German and Polish manufacturing companies

In the research results the identified core competence as a set of characteristics of employees for Industry 4.0 are scored as important (more than 4 with on five-point Likert scale) - see Fig. 2.

3 The Concept of an Intelligent System for Core-Competence Identification for Industry 4.0

The problem in this paper is how to assess the qualitative factors in core competences for Industry 4.0 in manufacturing companies, and how to select the employees with the appropriate skills to undertake projects in companies. The proposed approach, presenting the weightings of core competences, provides an opportunity to evaluate a potential employee in manufacturing companies. Therefore the following stages are involved in an intelligent system for core-competence identification (see Fig. 3).

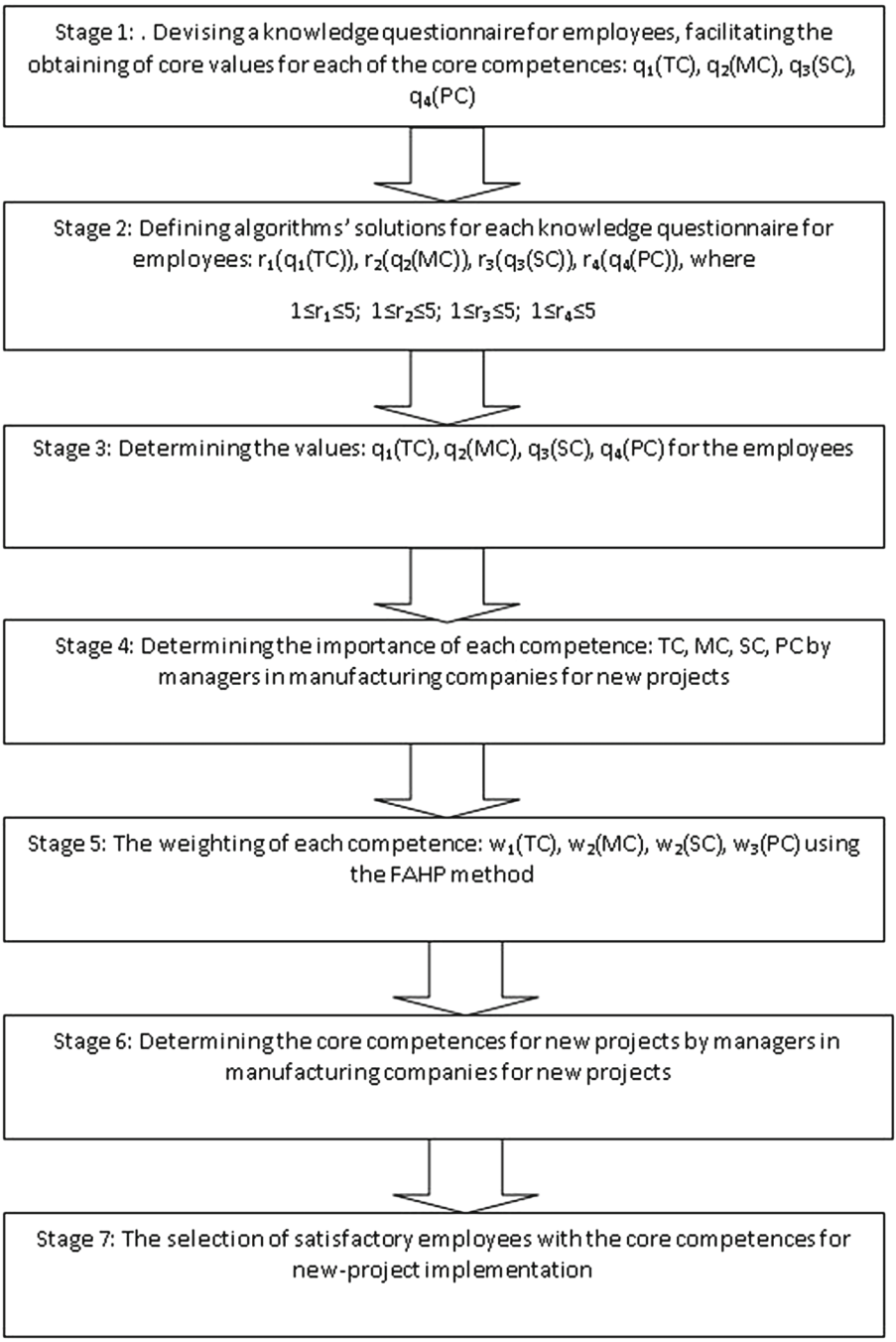

Fig. 3. The concept of an Intelligent system for core-competence identification for Industry 4.0

Stages one to three were based on the literature research results and empirical research results from German and Polish manufacturing companies (see Chapter 2). So we proposed four web-based questionnaires for each employee in the manufacturing companies in the survey to obtain values for each of the core competences q_1(TC), q_2(MC), q_3(SC), q_4(PC). The employees selected by the managers in the companies had to complete web-based questionnaires. He/she selected one answer for each question. Based on the results, and on the algorithms' solutions, values for each competence TC, MC, SC, PC for the employees were created.

In stages three & four the FAHP method (The Fuzzy Analytic Hierarchy Process) was implemented. Using FAHP it was possible to determine the relative predominance of a particular factor from the immeasurable elements of the framework for the core-competence model; furthermore it was possible to evaluate these factors. According to Nydick and Hill [9], a linguistic variable can be described by a fuzzy number $\tilde{a} = (l, m, u)$ with a triangular fuzzy-membership function. The triangular fuzzy number $\tilde{a} = (l, m, u)$ is defined in the set $[l, u]$, and its membership function takes a value equal to 1 at the point m. The fuzzy scale of preferences is strictly defined by Nydick and Hill [9]. Each group of competences is compared at peer level in terms of importance.

Stages five & six are outcome of the previous stages. The presented concept of an Intelligent system for core-competence identification for Industry 4.0 (see Fig. 3) in the form an IT tool was implemented and is presented in the next section.

4 An Intelligent System for Core-Competence Identification for Industry 4.0 (IS-CI)

Stages five & six are outcome of the previous stages. The presented concept of an Intelligent system for core-competence identification for Industry 4.0 (see Fig. 3) in the form an IT tool is implemented, and in the next section presented.

In order to illustrate the possibility of answers to our research questions, let us consider the situation: the problem being considered entails selecting employees with the appropriate abilities to undertake new projects in a company, involving Industry 4.0.

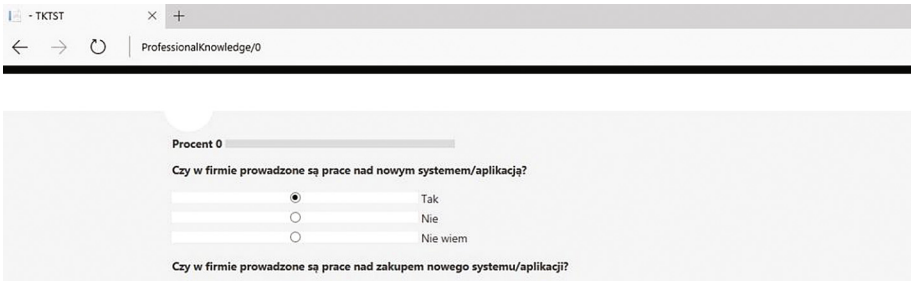

Fig. 4. An extract from the web questionnaire for employees facilitating the determining of core competences - technical competencies in IS-CI (the web-questionnaire is currently only in the Polish language)

Below is an extract from the Intelligent system for core-competence identification for Industry 4.0, based on the proposed concept (see Fig. 3).

According to Stage 1 (see Fig. 3) for each core competence a knowledge web-questionnaire is defined. Figure 4 presents an extract from the web-questionnaire for employees facilitating the obtaining of values for core competences: technical competencies.

According to Stage 2 in Fig. 3, the defined and implemented algorithms' solutions for each knowledge web-questionnaire enabled the obtaining of values for core competences - technical competencies - completed by the employee,

From the results we can derive the values of each competence: q1(TC), q_2(MC), q_3(SC), q_4(PC) for the employees - see Stage 3 in Fig. 3.

In the fourth stage of the proposed model, managers determine the importance of each competence - TC, MC, SC, PC - for new projects, according to the following rules.

- TC - equally important or moderately more important or of greater importance or of the most importance compared with MC.
- TC - equally important or moderately more important or of greater importance or of the most importance compared with SC.
- TC - equally important or moderately more important or of greater importance or of the most importance compared with PC.
- MC - equally important or moderately more important or of greater importance or of the most importance compared with SC.
- MC - equally important or moderately more important or of greater importance or of the most importance compared with PC.
- SC - equally important or moderately more important or of greater importance or of the most importance compared with PC.
- PC - equally important or moderately more important or of greater importance or of the most importance compared with TC.
- PC - equally important or moderately more important or of greater importance or of the most importance compared with MC.
- PC - equally important or moderately more important or of greater importance or of the most importance compared with SC.

Fig. 5. An extract from the use of the FAHP method for the weightings (the importance) of the of the core-competence identification for new projects in the IS-CI (the determination of the importance of each competence is currently only in the Polish language)

According to the defined rules, the FAHP method was implemented and used. Based on the fuzzy scale of preferences, the fuzzy weightings matrix of core competences for new projects was defined. By the use the FAHP method, the weightings of the of the core competences for new projects were assigned - Stage 4 -the weighting of each competence: w_1(TC), w_2(MC), w_3(SC), w_4(PC) using the FAHP method - see Fig. 5.

Therefore, by using the FAHP method, it is stated, that the most-important core competence of employees for the new-project implementation is – see Fig. 6.

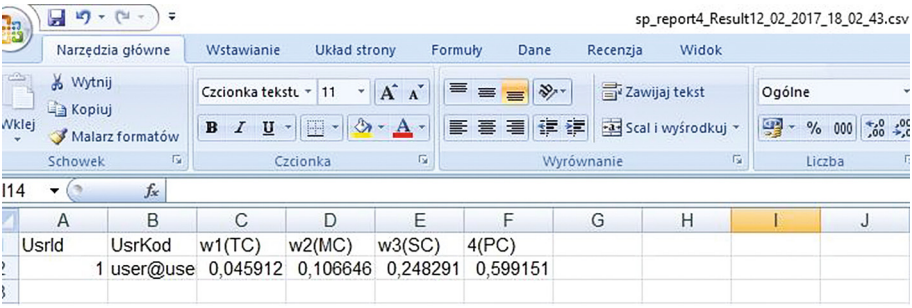

Fig. 6. An extract from the defining of core competences for new projects by managers in manufacturing companies for new projects in the IS-CI

So, the results are similar to the research results from German and Polish manufacturing companies (see Fig. 2). The most-important competences are personal competencies (PC) for new-project implementation.

In the stage seventh the managers select the satisfactory employees with the core competences for new project implementation based on the set of the values of each competence: q_1(TC), q_2(MC), q_3(SC), q_4(PC) for the employees (see stage 3, Fig. 3).

Naturally, this concept for the Intelligent system for core-competence identification for Industry 4.0 is dynamic, and can be adapted to the needs of companies. Besides, the whole proposed system is a tool which can be modified to the needs of the company and can be adaptable to the profile of the company.

5 Conclusions

The research results from the German and Polish manufacturing companies surveyed in this study show the importance of competences, and also the characteristics of employees, in the context of the ability to absorb and use new technology in Industry 4.0. We can also observe the need to build an intelligent system to support the selection process of satisfactory employees with the core competences for new-project implementation in manufacturing companies. Our case study presents an intelligent system for core-competence identification for Industry 4.0 (IS-CI). This concept will be further developed in our future work.

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