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Conceptualization of an AI-based Skills Forecasting Model for Small and Medium-Sized Enterprises (SMEs)

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Abstract

Forecasting-based skills management, which is oriented to the respective corporate goals, is gaining enormous importance as a central management tool. The aim is to predict future skills requirements and match them with existing interorganizational skills. Companies are required to anticipate changes in markets, industries, and technologies at an early stage as well as to identify changes in job profiles within an occupational profile by tapping into and evaluating various data sources. Based on these findings, they can then make informed decisions regarding skill gaps, for example, to implement targeted further training measures. Forecasting-based skills management offers the opportunity to optimally qualify employees for constantly changing tasks. At the same time, however, the targeted development of such skills requires a high level of time, financial and personnel resources, which small and medium-sized enterprises (SMEs) generally do not have at their disposal. In addition, many SMEs are not yet aware of the importance of this issue. Within the framework of research and industrial projects of the Smart Work department at the FIR (Institute for Industrial Management) at the RWTH Aachen University, an AI-based skills forecasting tool will be developed. The goal of the paper is to conceptualize the future machine learning method, that is able to generate individualized skills forecasts and recommendations for SMEs. This is achieved by linking societal forecasts and sector trends with company-specific conditions and skills. In order to generate a corresponding database, the derivation system is made available to various companies (large companies and SMEs) in order to obtain as many data sets as possible. The data sets obtained via the derivation system are then used as training data sets for the machine learning method, with the help of which an automatic derivation of competencies depending on new trends is to be made possible.

Keywords

Skills Management; Changing Markets; Future Skills; Employee Qualification; AI; SMEs; Company-specific conditions; Skill Forecasting; Competencies.

1. Introduction

The world of work is currently undergoing profound change, the central drivers of which are digitization and automation, the complexity and dynamics of markets, and demographic change [1,2]. Increasing complexity and growing dynamics of global markets are leading to massive pressure to innovate, which requires companies to be highly flexible to constantly adapt to changing conditions. Digital technologies enable new forms of communication that fundamentally change social relationships, social structures, and inter- and intraorganizational forms of cooperation [3]. This development was accelerated to a great extent by the COVID-19 pandemic. The digital transformation, which has been driven forward with vigor for years, has turned from a much-discussed future scenario into an everyday working environment. The developments outlined are accompanied by major changes in terms of the competence requirements of employees [4]. New

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competence requirements and even completely new job profiles are emerging, whereby competence is understood as a collection of skills that contribute to successful action [5]. According to a study by Bughin et al., the need for physical and manual skills will decline. Instead, more complex, cognitive skills and technological know-how will be of interest [6]. Against this background, the Organization for Economic Cooperation and Development (OECD) has found evidence in a study that there is already a deficit between the job requirements and the existing competencies of the employees [7]. For this reason, individualized forecast-based competence management, which is oriented to the respective corporate goals, is gaining enormous importance as a central management tool. The aim is to predict future competence requirements and to match them with existing internal competences [8]. Such competence management offers the opportunity to optimally qualify employees for the constantly changing tasks. However, the financial, human and time resources required for this can hardly be found in small and medium-sized enterprises (SMEs) in particular [9,10]. SMEs are thus faced with the challenge of proactively managing the tension between individualized forecast-based competence management on the one hand and resource bottlenecks on the other. Within the framework of research and industrial projects of the Smart Work department at the FIR (Institute for Industrial Management) at the RWTH Aachen University, the goal of conceptualizing a forecast-based assessment procedure for deriving the competencies required in SMEs in the future and, accordingly, developing education contents is pursued. Thus, an active contribution to existing research in the context of skills forecasting and skills assessment in SMEs is made.

2. Economic relevance for SMEs

An essential prerequisite for future-oriented corporate alignment is the early recognition of market trends or megatrends, which can result from various causes (e. g., consumer trends, product trends, social trends, political trends). In order to be able to react adequately to these trends, they must be analyzed continuously and the employees must be qualified at an early stage, taking the new trends into account [11,12]. In this regard, the concept of life-long learning [4] has become established in the specialist literature, through which the further education of employees with regard to changing environmental influences, e. g. in manufacturing companies, is to be sustainably anchored. Against this background, learning is becoming a strategic competitive advantage of companies and should therefore find its way into the company's objectives [13]. If we look at the reasons for the still relatively low learning and competence orientation in SMEs, various scientific-technical and economic aspects can be cited. The existing models of competence forecasting for SMEs are only of limited use. They only provide first action implications for implementation and application. It is therefore often necessary to design a new model that takes company-specific conditions and competencies (currently prevailing and future relevant) into account and compares them with the sector-specific forecasts. However, due to the lack of time, financial and human resources outlined above, SMEs are often not in a position to do this. [9,10]. Against the background of this need for action, the central research question of how and in what form a prognosis-based competence assessment can be carried out in SMEs needs to be answered. The focus lies on the conception of a generally applicable guideline that generates individualized competence forecasts and recommendations for SMEs. Consequently, a high cross-sector innovation potential can be offered: By analyzing future market developments and trends in the field of production technologies, developments, and method, developments relevant to competition can be made transparent at an early stage and communicated to SMEs.

In summary, a multidimensional challenge for SMEs can be identified, which results from the lack of the possibility to analyze market- and megatrends and to determine their effects in a targeted manner for their own business field. In order to carry out and link these analyses with the goal of identifying and balancing the necessary qualification needs of the employees, there are major time, financial and capacity risks. Thus, these risks stand in the way of preventing the loss of the company's market position. Due to the high economic importance of German SMEs [14], a research-based solution is needed to reduce the

aforementioned prevention risks in order to enable SMEs to adapt their strategic orientation and thus strengthen their own market position. Therefore, the goal is to develop a tool that enables the determination of market and technology developments and matches existing skills with future needs based on a data-driven trend forecast. As a result, companies receive an overview of the resulting competence gaps, which can be used to derive suitable further training offers.

3. Scientific-technical approach

To delve further into the topic, it is first mandatory to define the concept of competence. The term competence is defined as a collection of prerequisites or skills that contribute to successful action [5]. Competencies include the skills required to perform a task [15]. An example is the European Classification of Skills, Competences, Qualifications and Occupations Platform (short: ESCO) [16]. Its aim is to generate a uniform classification in the subject areas of occupations, skills and qualifications in order to increase efficiency in the European labor market and improve the integration of education into the labor market [16]. The classification comprises five categories. The first category includes skills such as general equipment operation or even basic manual skills. The second category includes skills such as data entry and data processing. Possible activities include providing basic information or maintaining operational and sales designations. In contrast, the third category describes higher cognitive skills. This category includes activities such as managing and maintaining product inventories or complex information processing and interpretation. In addition, the fourth area includes social and emotional skills and the fifth all technological skills. Here, a distinction is made between different technology levels, for example between basic digital skills and advanced IT and advanced data analysis skills.

3.1 Competence forecasting and competence forecasting models

Competence forecasts represent a central control element for the further training of employees [17]. There are, for example, forecasts for the strategic assessment of future competence requirements on the labor market [8]. The goal is to create a balance between the supply and demand of competencies through the anticipation of competencies [8]. A number of different methods and instruments can be found in the literature to anticipate future needs and relevant skills. The most commonly used instruments include employer and employee surveys, sector analyses and general labor market studies [18].

In the literature, the term model is defined as a simplified representation of a section of reality [19,20]. According to Stachowiak, models contain three essential features: Mapping or accuracy, foreshortening, and pragmatism. [21]. Moreover, models represent different elements of reality. Depending on the objective, for example, the structure or even the functioning of a reality can be depicted exactly. At the same time, however, models only represent a section of reality. Furthermore, a model is tailored to an individual purpose of investigation. For this purpose, it is necessary to define for whom and for what purpose the model in question is being developed [21]. As an additional determinant, verification and validation must also be taken into account [22,23]. Accordingly, the aim of competence forecast models is to depict the future working world as realistically as possible. To achieve the most realistic depiction possible, situational (e. g. sector-specific conditions) as well as individual, company-specific conditions should be considered. According to a study by Campion et al., the company context and the individual company goals must be taken into account for the identification of competencies [24]. Furthermore, a combination of different analysis methods is necessary to compensate for method limitations. The third component to be considered is the purpose of the investigation: To ensure successful application, subsequent model verification and validation in companies is required. It is necessary to verify whether the model answers the actual research question and can deliver the desired results [25,23].

In the context of competencies that will be relevant in the future, four models in particular are of interest and are presented in overview form in the following table 1. For better comprehensibility, the models are named after the responsible institutions. They differ in structure, design, and approach.

Table 1: Competence models (own representation)

Pearson and Nesta (2017) [26]	McKinsey & Company (2018) [6]	World Economic Forum (2018) [27]	Stifterverband (2017) [28]
• Status quo analysis (influences and trends) • Discussion and future scenarios • Predictions of activity requirements • Predicion of future relevant capabilities • Results and implications	• Status quo analysis (influences and trends) • Skills classification • Company surveys on the topic of the influence of automation and AI on • Organizations Quantification of activity and capability changes • Results and implications	• Status quo analysis (influence and trends) • Conception of company questionnaire considering relevant dimensions • Presentation of future skills and activities • Results and implications	• Status quo analysis (Identification of prevailing competence challenges) • Conducting company surveys and interviews • Deriving a future skills framework • Results and implications

The four models outlined above represent relevant capabilities for the future. However, while the models of McKinsey & Company and the World Economic Forum (WEF) can be applied to different countries and regions, the models of Pearson and Nesta and the Stifterverband focus on individual countries (UK and USA or Germany). All models consider situational factors (such as sector or region specifics) or identify trends, influencing and changing factors. However, individual, or company-specific factors are not considered separately in the analysis. In addition, although companies are considered as a target group, the results are not directly applicable to companies on an individual basis. Only the models of Pearson and Nesta, McKinsey & Company and the WEF provide initial action implications for implementation and application in companies. The individuality of the (competence) forecasts is also limited. The planned model is expected to close these gaps.

3.3 Machine learnings models or algorithms

Machine learning is a method of teaching computers to learn from data, without being explicitly programmed. It involves using algorithms and statistical models to analyze and make predictions based on data. There are three main types of machine learning: supervised learning, unsupervised learning, and reinforcement learning [29].

In supervised learning, the computer is given a dataset with labeled examples (input and the corresponding desired output) and uses these examples to learn a general rule that can be used to predict the output for new, unseen examples. This type of machine learning is used for tasks such as image classification, speech recognition, and natural language processing. Unsupervised learning, on the other hand, the computer is given a dataset without labeled examples and must find patterns and relationships within the data on its own. This type of machine learning is used for tasks such as anomaly detection, clustering, and dimensionality reduction. Reinforcement learning is a type of learning where an agent learns to make decisions by interacting with its environment and receiving feedback in the form of rewards or penalties. It is used in applications such as robotics, game playing, and autonomous vehicles. [30–32]

Predicting the skills that will be in demand for SMEs in the next five years will be a complex problem, and there is no universal answer when it comes to the best machine learning model or algorithm. However, some models and algorithms that may be well-suited for this problem include:

- **Random Forest:** Random Forest is an ensemble method that combines multiple decision trees to improve the accuracy of predictions. It can be used to identify important features in the data and make predictions about future skills demand.
- **Gradient Boosting Machine (GBM):** GBM is an ensemble method that is particularly useful for predicting a continuous target variable. Like Random Forest, it also identifies important features. It can be used to predict future skills demand for SMEs.
- **Time Series Analysis**: Time series analysis can be used to analyze and forecast trends in the data over time, which can be useful for predicting future skills demand for SMEs.
- **Natural Language Processing (NLP):** NLP can be used to analyze unstructured data such as job postings and resumes, which can be used to predict future skills demand for SMEs.
- **Machine Learning model based on clustering**: Clustering algorithms like K-means, Hierarchical clustering etc can be used to group similar jobs or skills together and then use the group to predict the future skills demand. [30,33]

It is important to note that the best model or algorithm will depend on the specific problem, e. g. industry, region, social transformations, which is to be observed, as well as the characteristics of the data. The performance of the respective models and algorithms using appropriate evaluation metrics need to be evaluated and lastly, the best performing model needs to be selected.

3.2 Working hypothesis

Based on the previously presented research idea for the conceptual design of a prognosis-based assessment procedure for the derivation of future required competencies in SMEs, the following hypotheses can be derived, which will be investigated and processed within the scope of the work packages:

- Information about the existing competencies of employees (also outside their direct field of work) is only available to a limited extent, especially in SMEs.
- SMEs could increase the employability of their own employees through competence forecasts and also expand their business areas in the long term.
- Lack of expertise as well as unidentified skills gaps lead to sub-optimal employee deployment as well as productivity losses.
- In the long term, a competence assessment based on well-founded forecasts could also significantly increase the development opportunities of employees and their satisfaction.

Since forecasting future trends is very time-consuming, SMEs often react late to the need for new or changed competencies and skills. A central prerequisite for targeted training and workforce planning is the recording of existing competencies in the company and their comparison with the required competencies. This requires new IT tools that enable SMEs to comprehensively record the competence profiles of their employees and to reflect technological developments with regard to the requirements. Taking the formulated hypotheses into account, the following overarching working hypothesis emerges:

Overall working hypothesis:

The development and provision of a tool for competency assessment enables SMEs to deploy their employees in a targeted manner and to close existing competency gaps in line with their needs. In addition, the prospective analysis and forecasting of future technology and development trends enables an early response to necessary competence requirements and opens up potential for productivity and efficiency increases across all levels of the company.

4. Method

Within the conceptualization of the AI-based skills forecasting tool, a complex problem will be investigated, which, due to its various main topics, such as

- the trend forecast for sales markets and market developments,
- the networking of people and technology, and
- the competence prognosis and the competence evaluation,

has a high interdisciplinarity. Findings from previous research projects (e. g., the Labor Science Competence Center for Gainful Employment in Industry 4.0 (LIMo) project conducted by FIR (Institute for Industrial Management) at the RWTH Aachen University) are taken into account for further development. The preliminary work from these research projects will be used to determine the necessary data basis for the trend forecast. At the same time, these projects have already successfully integrated new technologies in industry with the help of selection aids and implementation aids, so that the comprehensive results and findings obtained here will be transferred as preliminary work. To achieve the machine learning tool, the process is split up in six steps. In the following chapter, the processing steps are presented in more detail.

4.1 Processing steps

The aim of the first step is to develop a catalog of requirements for the recording and assessment of competencies in SMEs. In a first measure, the required competencies (e. g. technical and methodological competencies, personal competencies, social competencies, activity and action competencies, digital competencies) are to be examined and identified with regard to their relevance to the research objective [34]. Based on this, the methods and software solutions already available on the market for screening the identified employee competencies are to be identified with the help of a market research [35–38]. Subsequently, their industrial suitability is to be discussed and evaluated with the help of semi-structured interviews with experts of partner and application companies and essential obstacles regarding their use in SMEs are to be identified. In addition, the existing solutions are evaluated regarding competence acquisition in SMEs, taking into account the typical problems of SMEs. Finally, the results of the market research and the interviews with experts will be translated into requirements for the methodology to be developed and transferred into a requirements catalog.

The goal of the second step is to develop the competence morphologies, segmentation and classification of competences required to achieve the research objective. This measure is based on the assumption that employees, regardless of their education, have different competencies, the targeted use and promotion of which generate considerable added value for the system as a whole [39]. Within the framework of the competence morphologies to be developed, the relations between the available competences of employees and the value of these competences for the performance of a defined activity are to be highlighted. For this purpose, the operational activities in production and logistics of SMEs are to be clustered into activity groups and each activity group is to be assigned the competencies required to perform its activities. The basis for this is literature research, in the context of which the different activities in production and logistics are summarized as clusters. Subsequently, with the help of further expert interviews and the analysis of job advertisements on job portals and in the environment of the partner companies, the skills required for each activity are identified and related to the activities by means of an assignment table. In addition to technical and methodological competencies, personal, social, activity and action competencies as well as digital competencies must also be considered. At the same time, interviews with experts are to be used to identify the typical training occupations of operational employees and to examine them in terms of the competencies they have learned. Analogous to the first step, the results will also be put into relation to one another with the help of an assignment table.

The third step focusses on development of the concept for enabling SMEs to identify required competencies at an early stage regarding forecast technology and development trends. The starting point in this respect is the derivation of upcoming industrial and sector-specific trends in the short and medium term. As described in the previous chapters, the automotive industry plays a pioneering role regarding technology and development trends, which is to be used to identify future developments and market trends for SMEs. The analysis of these trends will be done by literature research, the results of which will be discussed and verified in interviews with the partner companies of the automotive industry as well as other large companies of the industry. In the interviews, the reaction of the automotive companies to the necessary competence requirements (technical and methodological competence, personal competence, social competence, activity and action competence) will also be examined. In doing so, it will be analyzed to what extent trends from the automotive industry also apply to SMEs in the pure single-item manufacturing sector, or whether there are deviations which may require separate analyses. The result is a reference process for deriving competence and training requirements from market trends. Based on the reference process, a derivation system is then developed that allows users to forecast the competence requirements associated with a market trend. To this end, users are asked various questions about the market trend in question. These questions are to be designed in such a way that their answers provide direct information about the type of trend (technological, social, etc.) and the required competencies. To be able to automatically derive competence requirements in the future, the use of machine learning methods is to be examined for this purpose. Since there is a correlation between market trends and the required competencies, the competencies are to be formalized and qualitatively predicted as a classification question. In order to generate a corresponding database, the derivation systematics will be made available to various companies (large enterprises and SMEs) in order to obtain as many data sets as possible. The data sets obtained via the derivation systematics are then used as training data sets for a machine learning procedure to be selected, with the help of which an automatic derivation of competencies depending on new trends is to be made possible. The development and market trends are to be prepared quantitatively in such a way that they can be processed automatically by a machine learning procedure.

The goal of the fourth step is the development of internal competence screening. In order to be able to compare the existing competencies with the required ones, a standardized system is needed to link the respective competencies with the departments and employees. For this purpose, both the required and the existing competencies must be prepared accordingly. To support users in entering the existing competencies, the conception of the internal assessments is planned for an implementation in Microsoft Excel VBA, which has a high user-friendliness and is based on Excel tables that can be created by any company. The competencies are to be entered via a corresponding user interface, via which the existing competencies can be linked to predefined departments and employees. The competencies entered are to be stored in structured flat tables, with the competencies being uniquely coded via primary keys. For this purpose, in addition to defining the table format, a coding catalog is to be created via which all competencies are assigned to unique primary keys. The competence requirements associated with the market trends were already derived in the third step but must also be transferred to structured tables and coded accordingly using the coding catalog. The subsequent comparison of competencies is performed by an iterative comparison of the primary keys of the required and existing competencies, so that a corresponding algorithm must be developed and implemented in the software. If a required competency is not available, the corresponding primary key is transferred to a separate output format, which provides the user with a clear list of the missing competencies after the comparison is complete.

To ensure the industrial applicability of the developed methodology, the partial concepts developed in the third and fourth step are to be combined in an IT-demonstrator. It should be noted that this must be an environment that is also frequently used by SMEs or can be easily adapted, such as Microsoft Excel or Python. The tool should be designed in such a way that the users can view the source code and adapt it if necessary. Consequently, it should be programmed in an open-source program, so that it can be made

available to the economy without barriers and can be adapted as needed. Of particular importance is the design of a user-friendly interface, so that the usability of the tool is guaranteed even without extensive IT knowledge. In addition, comprehensive documentation on the conception, use and implementation of the tool will be provided so that its structure and functionality can be viewed, thus ensuring autonomous use by the users beyond the duration of projects. For the selection of the programming language (Java, C++, Python, VBA) for the software-technical conversion of the derivative systematics therefore an benefit-cost analysis is to be accomplished regarding the pro and cons of the individual programming languages. In order to avoid interface problems, the competence requirements resulting from the questionnaire are to be output as flat Excel tables, which are automatically coded by the application of text mining methods and with the help of the coding catalog.

The methodology developed in the previous steps for recording competencies, forecasting future competency requirements, the targeted use of existing competency profiles and the expansion of competencies among employees, among other things to increase productivity and the economic factor in the company, is to be validated in this step. For this purpose, the screening concept will be applied to at least two partner companies. Various market trends are presented to the companies, from which a market trend suitable for the company's orientation is to be selected. Subsequently, the competence forecast, and the competence screening must be carried out accordingly and the required qualification must be identified. The validation and identification of improvement potentials regarding the methodology and the IT demonstrator, whose implementation is also part of the validation is accompanied scientifically. The sixth step concludes with the documentation of the procedure for competence forecasting as well as for competence screening and the use of the IT demonstrator in the form of a guide.

5. Feasibility and transfer of results

An important goal is the dissemination of the results achieved in the economy, in particular making them known to SMEs; from all sectors. Therefore, specific transfer measures will be implemented, which will be completed in different ways at different times. Nine measures are planned during the term of the project, i. e. the conceptualization of the AI-based skills forecasting tool, which are now presented here with the intended objective. First, project information will be presented on the Internet so that the current status of the work can be tracked. In this way, the websites of the participating research institutions will always reflect the status quo of the research, and additional companies will be attracted to the project. Meetings of the PA are initiated with the aim of discussing the research progress and agreeing on the further procedure. Through industry consultations and strengthening of the economic networks, the approach as well as the acquisition of potentially interested companies is to be optimized in the context of public relations. Measures are also to be taken in the passive information area. For example, results will be presented on knowledge platforms to promote an exchange and transfer of results to the (regional) economy. However, not only the knowledge platforms will be used for the publication of project results, but also the internal magazine of the FIR (Institute for Industrial Management) at the RWTH Aachen University, in which the project will be presented. In the sense of promoting young scientists, bachelor's and master's theses as well as project papers will also be written in the project. This serves to convey scientific knowledge in the subject area, as well as to introduce students to independent scientific work. Other written work, such as interim reports, will be published in professional journals (for example, the “Zeitschrift für wirtschaftlichen Fabrikbetrieb” (Journal for economical factory operation)). Also, the possibilities of project presentations on conferences and congresses are used (e. g. on the GfA conference). Finally, a final report is written, which follows the dissemination of the project results. Through the constant interaction of research and practice, companies are involved in the definition of the competence morphology, which enables the development of a user-friendly demonstrator for competence screening. For validation purposes, tests will be implemented in the environment of the partner companies and needs for improvement will be revealed. The research centers will support the first applications of the demonstrator, which will enable the long-term usability of the results

achieved. Furthermore, the finally developed IT demonstrator will be made available to interested companies. In addition, potential users will be able to access the results achieved and transfer them into business practice. In order to avoid additional costs for the companies using the demonstrator, the aim is to design the demonstrator on the basis of software solutions commonly used in SMEs or to develop it on the basis of common or license-free software that also allows adaptation to the individual needs of the users. This enables SMEs to use the competence screening and thus promote it internally without having to incur additional financial expenses.

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Biography

Charlotte Frierson (*1992) is a project manager in the department Smart Work at FIR (Institute for Industrial Management) at the RWTH Aachen University. She is a sociologist and passionate about diversity-oriented skills management and lifelong learning. In her previous work and research activities, she has gained different transdisciplinary experience, e. g. in production, and skills development in the field of diversity management.

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