PROFILING THE INDUSTRIAL ENGINEERING AND MANAGEMENT DISCIPLINE: KEY IMPLICATIONS AND PRELIMINARY EMPIRICAL EVIDENCE FROM AUSTRIA

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Abstract: *The industrial engineering and management (IEM) job profile includes working at the interface between engineering and management, for example, on the development of solutions for technical problems under economic premises. The processing and/or solution of these mostly interdisciplinary problems requires technical, managerial, and methodological competences, as well as interdisciplinary competences such as social and/or personal competences. The trend towards interdisciplinary competences can be justified by technological progress – keywords "Industry 4.0" and "Industry 5.0" - and by the advancing digitalization and sustainability debate that permeates all areas of life. Particularly in times of the twin transition, specialists and managers with interdisciplinary action competences are indispensable to be able to successfully master challenges in industry and society. This paper analyses the current trends regarding the IEM job profile based on the results of the Austrian IEM job profile study. It concludes with recommendations for a preliminary competence profile of IEM professionals.*

Keywords: Industrial Engineering and Management, Engineering Education, Competence Profile, Job Profile Study

1. INTRODUCTION

Industrial engineering and management professionals (IEM) operate at the intersection of technology and business, where they tackle technical problems while considering economic premises. Bauer (Bauer 2015) emphasizes that IEM professionals should address three key questions: whether the problem is technically solvable, if it makes economic sense, and whether it benefits or harms society. Resolving these interdisciplinary problems necessitates a combination of technical and business expertise, methodological, and social competences. IEM professionals today have a crucial role in addressing global challenges like climate change, resource scarcity, and energy transition while considering economic competitiveness, environmental protection, and social acceptance. Recent studies highlight the growing demand for qualified engineers in smart and sustainable operations management (OM). Operations Management (OM) encompasses a range of tasks, including organizing work, selecting processes, arranging layouts, locating facilities, designing jobs, measuring performance, controlling quality, scheduling work, managing inventory, and planning production. Operations Managers are versatile individuals who are known as the "improvement people" and are responsible for planning, coordinating, and negotiating. Due to the diverse nature of their role, operations managers require various competencies, including technical skills, conceptual skills, methodological competencies like presentation skills, and transversal competencies such as communication and negotiation skills. The field of OM has been shaped and evolved by technological, economic, environmental, and social revolutions, with the expectation that the Green Revolution will bring the next evolutionary step. Operations can be understood as a transformation process that converts inputs into outputs of greater value, spanning the entire supply chain and being relevant to all functions within an organization. Consequently, any manager should have some understanding of the principles and concepts of operations management. In this context, Slack et al. (Slack et al. 2009) distinguish between two meanings of "operations": as a function within an organization that produces products and services, and as the overall management of all processes across all corporate functions (Russell 2011).

According to research by the Institute of the German Economy, there is a projected need for 48,300 engineers and 68,800 STEM academics annually between 2023 and 2028 (iW Köln 2020). In Austria, IT and engineering are identified as the most significant areas for skilled labor demand in 2021 (Statista.de 2021). Thus, flexibility, adaptability, resilience, and competences in the IEM area in the OM discipline are regarded

as vital success factors to enhance long-term competitiveness, both nationally and internationally. In fact,, today´s IEM job profile requires a diverse set of skills, attitudes, and competences, which Klamert-Schmid et al. (Klamert-Schmid et al. 2021) define as a "colorful bouquet." These competences are necessary for IEM professionals to effectively navigate the intersection between technology and business. However, to the best of the author´s knowledge, profound empirical study regarding the composition of competences for IEM professionals are still missing.
This paper presents preliminary results of the Austrian IEM job profile study 2022. The second chapter provides an overview of the study procedure and chapter three is devoted to the descriptive results. In the final chapter, conclusions are derived in addition to a summary.

2. METHODS

The methods of this paper will be briefly described in the next paragraphs. In gerneal, a standardized research methodogly based on validated measurement instruments are most commonly used in quantitative social research to statistically examine samples that are as representative as possible. The epistemological interest of this paper follows Karl Popper´s critical rationalism as a scientific theoretical approach. In this regard, critical rationalism as an experiential theory builds on theories and follows a systematic research design for collecting and analyzing empirical data (Albert 2011). Therefore, Döring and Bortz (Döring und Bortz 2016) follow a commonly used nine-phase model for empirical quantitative research, which structures the research process in quantitative empirical studies (see also (Bryman 2008; Neumann 2003). The sequential process is shown in Figure 1. and briefly described below.

Figure 1: Research Process(Döring und Bortz 2016)

Steps 1 and 2 are already included in the introduction section of this paper. The results of this paper are based on the outcomes of the recent job profile study of the Austrian Association of Industrial Engineers (WING). WING conducts a job profile study every four years to analyze trends and advancements in the techno-economic field. The study aims to provide transparent information about educational content, training opportunities, and potential career paths in the industry. The study was conducted under the supervision of the Institute of Business Economics and Industrial Sociology at Graz University of Technology. To ensure comparability, previous studies from 2014 and 2018 were used as a framework, and contemporary theories and questions were incorporated into the questionnaire. Different questionnaires were designed for IEM students, professionals, and human resource managers, containing a total of 163 questions for students and professionals and 42 questions for HR managers. Feedback from 30 IEM students and professionals was collected during the pretest phase to refine the questionnaires. A second internal pretest was conducted at TU Graz. The final questionnaire aims to describe the characteristics of prospective and practicing industrial engineers.
In the process of operationalization, theoretical concepts were defined and developed before data collection, following a deductive approach. The scientific theory of critical rationalism guided this process, which aimed to gather individual characteristics of social reality without claiming to be exhaustive. The questionnaire for students and graduates covered seven categories: demographic data, education, career

entry and path, further education, IEM competences, digitalization, and services provided by the WING association.
The job profile study utilized a random sample survey methodology. The construction of the sample varied depending on the target group. For students, the sample was determined by analyzing secondary data on training programs at Austrian tertiary educational institutions. Alumni were recruited through alumni networks of educational institutions and the WING member network. Personal contact with university interfaces, such as alumni networks, institute secretariats, and professors, was used to reach out to alumni. Additionally, the study and survey invitation were actively promoted within the WING network and at networking events. In summary, the survey was sent to a total of 9,758 persons (N) (7,478 IEM students and 2,280 IEM professionals), while 1,219 persons (803 fully completed) completed the survey, so the response rate is 12.5%.
The fully structured study involved personal contact with the relevant multipliers, such as alumni networks or secretariats, before the survey. The questionnaire was programmed using the LimeSurvey tool and made available online for participants to complete. An initial invitation E-mail containing the survey links was sent out at the beginning of the study. The questionnaire remained active for four weeks. After two weeks, a reminder was sent to all recipients, requesting them to forward the questionnaire to others.
The LimeSurvey program used in the study provided various analysis options within the program itself. Additionally, the data sets could be directly exported as SPSS-compatible files. The questionnaire was programmed with careful consideration of answer scales and sub-questions, allowing for easy transfer of data into the statistical program IBM SPSS Statistics v.26. Data quality was ensured by addressing criteria such as completeness, uniformity, exclusion of duplicate values, proper treatment of missing values, and plausibility of response patterns, as outlined by Schendera (Schendera 2007). Data cleaning and recoding of reverse-coded items were performed in the final step of the analysis.
Exemplary descriptive results of the survey for the IEM students and professionals will be presented in more detail in the following chapter.

3. RESULTS

This section will briefly describe selected results of the IEM students and alumni job profile study. To begin, the demographic results of the survey will be described, followed by the results on IEM competences.

3.1 Demographic Data

Ratio IEM students and professionals and academic degree. Of the 803 completed questionnaires of IEM students and professionals, 340 questionnaires were completed by IEM students (42.34%) and 57.66% or 463 questionnaires were completed by IEM professionals. Figure 2 shows an overview of the academic degrees of the 463 IEM professionals. The majority, a total of 361, of the respondents have a master's degree or a diploma in engineering, which is equivalent to a master's degree. 56 people have a Ph.D. and 135 have a bachelor's degree.

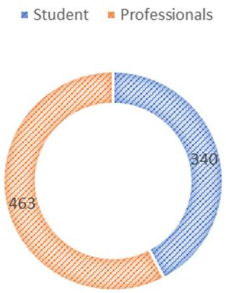

Figure 1: Ratio IEM students and professionals

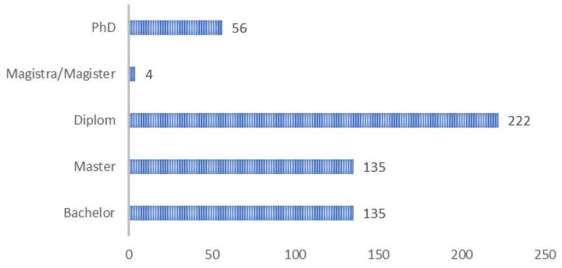

Figure 2: Academic degree

Age and years of experience. The age distribution of the completed questionnaires has a mean value of 33.29 years. The ages were divided into a total of six categories, with, for example, the first category comprising the age up to 30 years. A total of 488 people could be assigned to this first age category, followed by the second category up to 40 years with 112 responses. In addition, participants were asked how many years of professional experience they had both in the IEM discipline and overall in their professional careers to date. The mean number of years of professional experience in the IEM discipline is 10.79. The mean total number of years of professional experience is 15.06, which could be attributed to

the fact that survey participants did not work in any IEM industry-specific fields before or during their studies.

Industry Branch and Job Profile. Graphs 4 and 5 below show the distribution of industries and current job profiles from the target group. As already described in the introduction, the occupational field of an IEM is very diverse and by combining the teaching of technical and economic subjects, graduates have the opportunity to work in different industries and occupational positions. The definition of industries was taken from the nomenclature of the ÖNACE classification. However, as can be seen from the graphs, there are very clear trends in terms of industries. Most people, with a total of 109 responses, work in the manufacturing sector, followed by 39 or 11.47% in the education sector. 34 responses were in the construction sector. In each case, 0.29% (1 indication) were given for the areas "accomodation and food service activities", "arts, entertainment, and recreation", and "water supply/sewerage, waste management, and remediation activities". In terms of job profiles, there is a clear trend toward project management, with a total of 177 responses, followed by research and development/laboratory/Innovation with 155 responses.

Figure 3: Industry branch

Figure 4: Job profile

3.2 IEM Competence

The survey participants were asked what the ideal ratio of professional, methodological, and social competence would be in their respective functional areas. Professional competence is the ability to combine, deepen and critically examine subject-related and interdisciplinary knowledge and to apply it in contexts of action (Erpenbeck et al. 2017). Methodological competence comprises the interdisciplinary ability to apply working techniques, procedures, analysis techniques, and learning strategies. The term social competence subsumes interpersonal and intrapersonal competence. Interpersonal competence is the ability to cope with tasks that arise when dealing with people. Intrapersonal competence includes knowledge about one's person, i.e. personality-related skills (Erpenbeck et al. 2017; Frey und Balzer 2017; wba 2019a, 2019b). Solving interdisciplinary problems successfully requires a combination of solid theoretical knowledge, methods, and personal skills. Both the Austrian and German competence profiles recognize the importance of technical, methodological, and social competences, although they may differ in their specific forms (Abawi 2019; Bauer et al. 2022). The results of the respective mean values of the three aspects of competence are shown below in Figure 6.

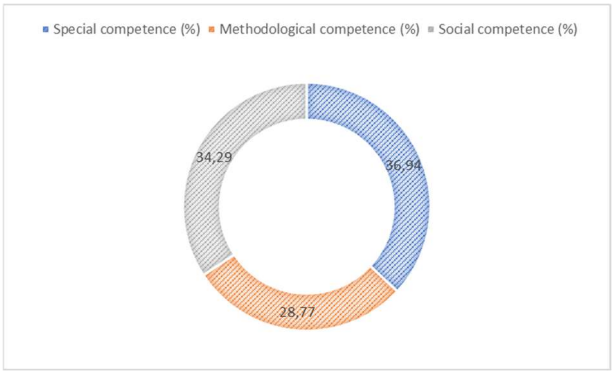

Figure 5: Overview of IEM competences

As the graph makes clear, the three areas of competence are similar in percentage terms, although a trend is discernible. Thus, professional competence seems to be most required for coping with professional

demands at 36.94%, followed by social competence at 34.29%. With 28.77%, methodological competence is behind technical and social competence in percentage terms.
In addition to the question about the relationship between technical, social, and methodological competence, the most frequently required foreign language skills as defined as one of the key competences by the OECD (OECD 2005, 2007), were also queried based on a multiple selection. As can be seen in Figure 7, English is by far the most frequently required foreign language with a total of 324 mentions, followed by French with 28, Italian with 27, and Spanish with 24 mentions.

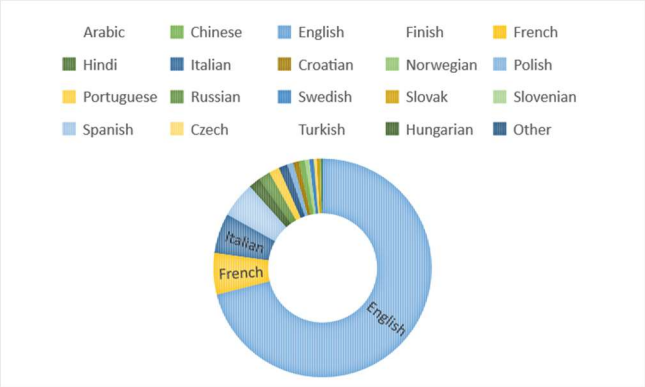

Figure 6: Foreign languages needed

4. SUMMARY AND CONCLUSIONS

The purpose of the 2022 job profile study is to survey current developments in the field on the one hand, and the needs and expectations of IEM students and IEM professionals on the other. This paper provided exemplary basic information on current and future conditions for IEM (future) professionals in the IEM fields and the current challenges faced by the OM discipline. Moreover, the results serve as a first baseline with implications for the realignment of an evidence-based competence framework for IEM and will help to prepare today the M-shaped engineers needed for tomorrow. Therefore, to ensure the quality, systematic growth, competitiveness, and employability of future engineers, it is crucial to establish universally applicable competences across the field of IEM. This requires collaborative efforts across disciplines to create evidence-based competence profiles (Rolf 2020). Based on the results of this study and other recent research achievements of the authors in this discipline, a complete competence profile of (future) IEM professionals will be developed. This competence profile is composed of the competence areas professional, digital, innovation competence, and transversal competences. The latter is in turn divided into interpersonal, intrapersonal, and methodological competences. The respective characteristics of the competence areas are to be a component of further investigations.

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