A COMPETENCE PORTFOLIO FOR FUTURE LEADERS IN ADVANCED SYSTEMS ENGINEERING

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ABSTRACT

Due to the increasing importance of advanced systems, whose development calls for interdisciplinary and integrative approaches, and fundamental changes in the work environment, leaders are required to have a wide range of competences. Therefore, the aim of this work is to identify competences of future leaders, that are specifically relevant in Advanced Systems Engineering (ASE). Thus, professional, social, methodological, and self competences developed by a literature review are validated through expert interviews and prioritized by a survey. The insights are then presented in a competence portfolio including 30 areas of competences. The portfolio consists of areas of competence that are either relevant in the context of ASE (e.g. intercultural and interdisciplinary competence), New Work (e.g. competence to empower employees) or are relevant to leaders in general. It was possible to add further aspects that are necessary in ASE to the aspects from the literature review. The experts interviewed emphasized various aspects of interdisciplinary work and made clear that in future, leaders should place their employees at the heart of their activities and empower them according to their strengths and weaknesses.

Keywords: New Work, Leadership Competences, Training, Systems Engineering (SE), Complexity

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1 INTRODUCTION

Due to the change from traditional products via mechatronic solutions to intelligent, cyber-physical systems (so-called Advanced Systems), more and more work is being done in cross-disciplinary development teams. The goal of Advanced Engineering is to develop successful Advanced Systems with the help of methods, processes, and tools as well as a suitable organizational structure and culture. Dumitrescu et al. (2021) write that Advanced Engineering can only succeed if the corporate culture allows employees a high degree of flexibility in terms of time and space. Life and work should also be compatible. The concept of New Work contains important elements that contribute to implementing the requirements of the Advanced Systems Engineering (ASE) mission statement. New Work focuses on employees and their personal needs, strengths, and weaknesses. In addition, New Work is associated with increased virtualization and flexibilization of work (Peters et al., 2009). Work in ASE and a changed working environment due to elements of the New Work concept require new competences and qualifications of the people involved (Grote et al., 2020). In addition to each individual team member, leaders in particular must be able to successfully enable teams in the development of Advanced Systems. The future relevance of those Advanced Systems is generally considered to be high (Keating et al., 2003). Thus leaders capable of leading teams in ASE are increasingly needed.
Therefore, the aim of this contribution is to analyse the specific requirements of future leaders in Advanced Systems Engineering while incorporating the elements of New Work. Finally an overview of the developed competences will be presented.

2 STATE OF THE ART

2.1 New ways of working for the development of advanced systems

A system is a set of interrelated entities (Keating et al., 2003). Hitchins (2003) adds to the concept of a system the cross-disciplinary characteristics: *interaction*, *configuration*, *architecture*, *containment*, *complementation*, *hierarchy*, and *emergence*. Furthermore, a system is the model of an entity that has relationships between different attributes such as inputs and outputs (Ropohl, 2009). When transferring the concept of a system to technical contexts, Ropohl (2009) describes the technical system as a system that is fundamentally located in a natural, technical, and social environment and that cannot be considered in isolation from human activity. The development of traditional systems since the end of the 19th century has led to more mechatronic systems through the electrification of systems and the integration of software (Isermann, 2008). The increasing digitization and the use of artificial intelligence led to the further development of systems towards Advanced Systems (Grote et al., 2020). According to Dumitrescu et al. (2021), Advanced Systems have the following four special features compared to mechatronic systems: *autonomy*, *dynamic networking*, *product-service interconnectivity*, and *sociotechnical interaction*. The increasing complexity of systems calls for an interdisciplinary and integrative approach that supports the successful realization of Advanced Systems through the use of systems principles and other methods and processes. The Advanced Systems Engineering mission statement addresses this need. The term Advanced Systems Engineering, as shaped by Dumitrescu et al. (2021), combines the concept of Advanced Systems with the approach of Systems Engineering (Sage & Rouse, 2009) and the aspect of Advanced Engineering. Advanced Engineering considers the processes, methods, and tools as well as the work organization to rethink the established engineering approaches with creativity, agility, and digitalization (Albers et al., 2022). Dumitrescu et al. (2021) describe that an organizational structure and culture are necessary to successfully implement Advanced Engineering. As pivotal aspects of this organizational structure and culture Dumitrescu et al. (2021) describe aspects such as flexibility in terms of time and space for engineers involved in the process, ensuring a work-life balance, working in distributed teams, and targeted use of methods (e.g agile development). This list illustrates that a fundamentally new understanding of work is necessary for successful Advanced Engineering. The new work concept is an important enabler for the successful implementation of Advanced Engineering as it embraces some of the main aspects addressed by Dumitrescu et al. (2021). New Work ist considered as is thought concept and movement at the same time (Hofman et al., 2019). The concept represents a rethinking of the understanding of work. This work is characterized by a high degree of virtualization of work tools,

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networking of people, and flexibilization of work locations, times, and content. New Work is also associated with agile, self-organized, and highly customer-oriented working principles. The concept also stands for the changed expectations of employees concerning participation, autonomy, and the creation of meaning through work (Hofman et al., 2019; Peters et al., 2009; Savić, 2020). Even though the original concept was first introduced by Frithjof Bergmn in the 1980s the concept has become very popular in the recent years due to developments such as COVID-19 and the digital transformation (Bergmann, 2019; Savić, 2020). Savić (2020, 102 f.) emphasizes the need for managers to adopt "different communication and management styles […] to properly lead and ensure the required level of productivity of a remote workforce" and thereore under those new working conditions.

2.2 Changing demands on future leaders

In the context of this paper, the following combined definition of *leadership* is used: "Leadership is a process of social influence. The precondition is that in a certain context some people accept a person as a leader to achieve common goals. Through procedural, systematic, and structured methods and behaviours, the leader causes people to willingly and enthusiastically invest energy in achieving goals." It includes all essential elements of leadership as they have evolved over the 20th and 21st centuries. In the future, the demands placed on leaders will change in a variety of ways. Von Au (2020) describes two major developments responsible for the changing demands on leaders. These are, on the one hand, changes due to the VUCA world. The acronym VUCA stands for Volatility, Uncertainty, Complexity, and Ambiguity and is seen as a driver of disruption (Millar et al., 2018). On the other hand, an observable change in values "from values of duty and acceptance to values of self-development and autonomy" changes the demands on leaders (Von Au, 2020, p. 101). This last aspect clearly illustrates how the idea of the New Work movement and principles such as self-responsibility, meaning, and development come increasingly into play. Von Au (2020) states that leaders must understand what their employees are passionate about and empower them according to their strengths and weaknesses. Various authors also describe changed requirements for future leaders in the context of Industry 4.0. Łupicka and Grzybowska (2018) list various technical competences that leaders must possess as a result of the developments resulting from Industry 4.0. These include media competence, programming skills, and knowledge management. An important goal here is an optimal alignment with customer needs. Leadership 4.0 also requires aspects such as rapid innovation, agility, and creativity (Venkatesh, 2020). Shet and Pereira (2021) also describe aspects such as collaborative mindset and sustainability as important competences for Industry 4.0. The state of research shows that there already is a good understanding and a vivid discussion on future competences of leaders. They focus on different societal and economical changes, namely VUCA world, Industry 4.0, and value changes. In all aspects, the individuals in the development team needs to be placed in the centre of all leaders' activitites (Albers, 2010). This only describes in parts the specific requirements of leaders in the development process for Advanced Systems.

2.3 Competences as abilities and skills to act adequately in variable situations

For the further research a clear understanding and a definition of what competences are and how they differentiate from other terms is of vital importance. The term *competence* is derived from the Latin word *competere* (to be capable of something, to compete) and thus already expresses the meaning very clearly (Wirtz, 2020). In the context of this paper, the following definition of competence is used: "Competence refers to an individual's ability and willingness to use professional, personal, social, and methodological skills and abilities to solve problems in variable situations." (based on Bundesministerium für Bildung und Forschung, 2022) Competences are usually divided into four dimensions: Self competences, professional competences, methodological competences, and social competences (North et al., 2013). Erpenbeck (2010) also emphasizes the difference between personality traits or character traits and competences: "Personality traits can change in the course of life, but can hardly be trained specifically. Competences change and can be developed, trained and managed in a planned way". (Erpenbeck, 2010, p. 81) In contrast to competences, traits are thus described as stable in the medium term. A good example for a competence is someone’s ability to work in interdisciplinary teams. In contrast to that, empathy can be seen as a personal trait.

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3 RESEARCH OBJECTIVE AND RESEARCH METHODOLOGY

The state of research indicates that work in engineering will change significantly as a result of the demands of developing Advanced Systems. Successful work in interdisciplinary teams and the use of new methods, processes, and tools will be of vital importance. At the same time, New Work will change the world of work in many ways. In chapter 2, it has been shown that New Work is an important enabler for successful Advanced Engineering and that the two concepts New Work and Advanced Engineering are closely linked. These changes will lead to new requirements for the competences of future leaders in ASE. The question arises of what competences are required by leaders of teams developing Advanced Systems while at the same time following the principles of New Work. Therefore, the goal of this contribution is to analyse the competences of future leaders in Advanced Systems Engineering and complement existing enumerations of competences with the specific requirements in developing Advanced Systems. Based on the results of this research, future leaders in ASE can manage their competence development in a targeted manner. Thus, the following research question is to be answered:

- What competences do leaders need to successfully lead teams in Advanced Systems engineering while incorporating the elements of New Work?

To answer the research question, a competence portfolio is developed in three steps (cf. Figure 1).

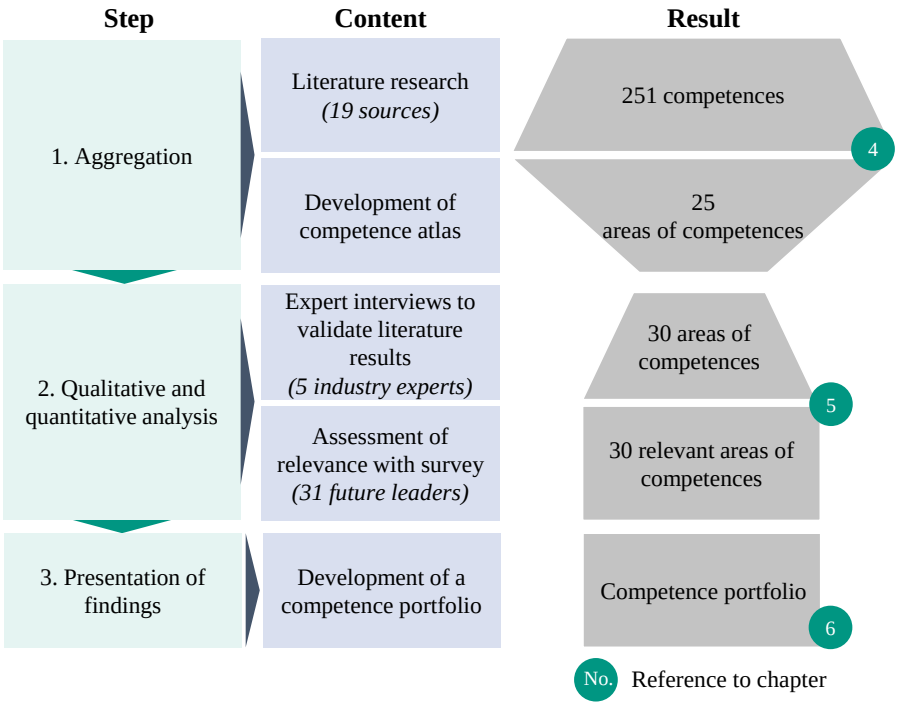

Figure 1. Methodology for analysing competences of future leaders

First, competences of future leaders based on the literature were aggregated into areas of competences. Therefore, literature was researched in which authors explicitly address the determination of competences that leaders will need in the future based on the synonyms for literature research in Figure 2.

Leadership competencies	Future of leadership	Leadership in New Work environment	Technical leadership	Leadership in product development	Leadership 4.0
Requirements for leaders	Requirements for future leaders	New leadership	Engineering leadership	Leadership in system development	Digital leadership
	Competencies of future leaders	New leadership competencies		Leadership in Systems Engineering	Agile leadership

Figure 2. Synonyms for literature research divided into thematic columns

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Second, a qualitative and quantitative analysis of the identified competences was conducted. Therefore, five experts with expertise in the development of Advanced Systems, product development, or in leadership in the context of New Work were interviewed. Figure 3 shows their expertise in the three relevant fields *Leadership*, *New Work* and *ASE*. 0 stands for no expertise in the corresponding field and 2 for a great expertise.

	Leadership	New Work	ASE
Expert 1	2	1	2
Expert 2	1	0	2
Expert 3	2	2	0
Expert 4	2	0	1
Expert 5	2	1	1

0=no expertise; 1=low expertise; 2=high expertise

Figure 3. Experience of the interviewed experts

The interviews followed a semi-structured approach by discussing all identified areas of competences and giving time to discuss further not mentioned competences. Following, 31 future leaders with an engineering background evaluated the relevance of each competence on a Likert scale from 0 (no relevance) to 4 (very high relevance). Third, a competence portfolio was developed presenting the 30 most relevant areas of competences for future leaders in ASE and New Work.

4 THE COMPETENCE ATLAS PRESENTS RELEVANT COMPETENCES FOR FUTURE LEADERS

For the aggregation of competences from the existing literature the following four steps were performed: literature research, analysis of competences, elimination of personality traits, and development of competence atlas. The four steps, the corresponding methods, and results are shown in Figure 4.

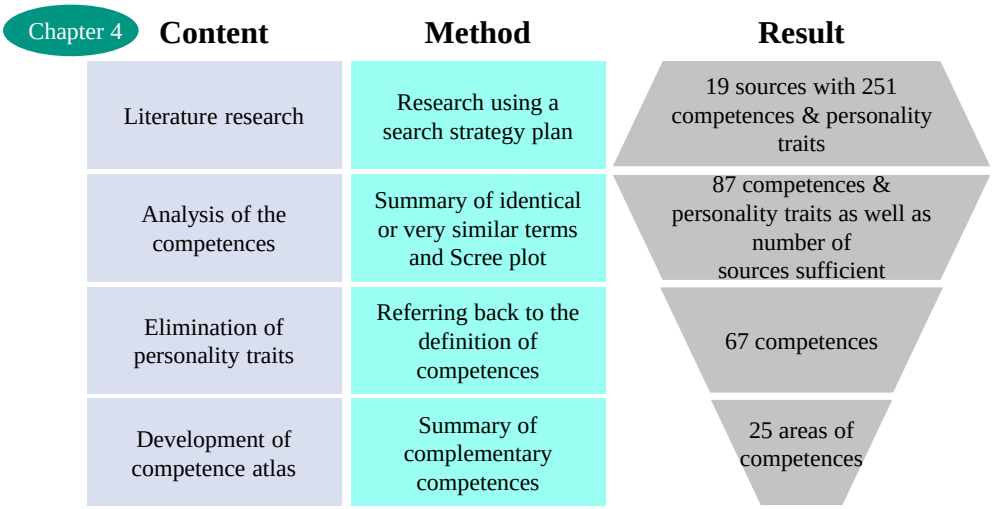

Figure 4. Steps for the aggregation of the competence atlas

As part of the literature research, 19 sources were researched and analysed in which the authors explicitly address the determination of competences, that future leaders will need. The sources analysed are various internet articles, journals, and scientific literature. The methodology used by the authors of the analysed articles includes individual experts' opinions, results of expert interviews and surveys as well as detailed literature analyses that itself analysed between 14 and 851 sources. The focus of the results was on different aspects. For example, some sources were identified that dealt with leadership in the context of Industry 4.0 (also called Leadership 4.0). Some sources focused on digital aspects (digital leadership). The authors mention different numbers of competences (6 to 34). Throughout the literature

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research, a total of 251 competences were identified. The result of combining the same or very similar terms is 87 different competences that can be assigned to the four dimensions of competences as presented in section 2.3. To ensure sufficient sources were used, a scree plot was conducted (see Cattell, 1966). Therefore, the eigenvalue as the number of new competences added was determined for each source and was presented in a graph, The criterion for completing the search, when the "elbow" of the graph can be seen (Cattell, 1966), was reached after source four. Due to the diversity of aspects of the topic (see research strategy plan in chapter 3), the search has been continued for additional sources. This was to ensure that all aspects of the topic were sufficiently illuminated within the literature review.
Subsequently those elements that were seen as personality traits and not as competences were eliminated. Finally, areas of competences were built by grouping complementary terms. For example, the area *digital competence* consists of aspects such as the ability to use the potential of digital technologies as well as basic programming skills. The competence atlas, which is presented in Figure 5, is the aggregation of all competences as a list of the 25 areas of competences that were developed.

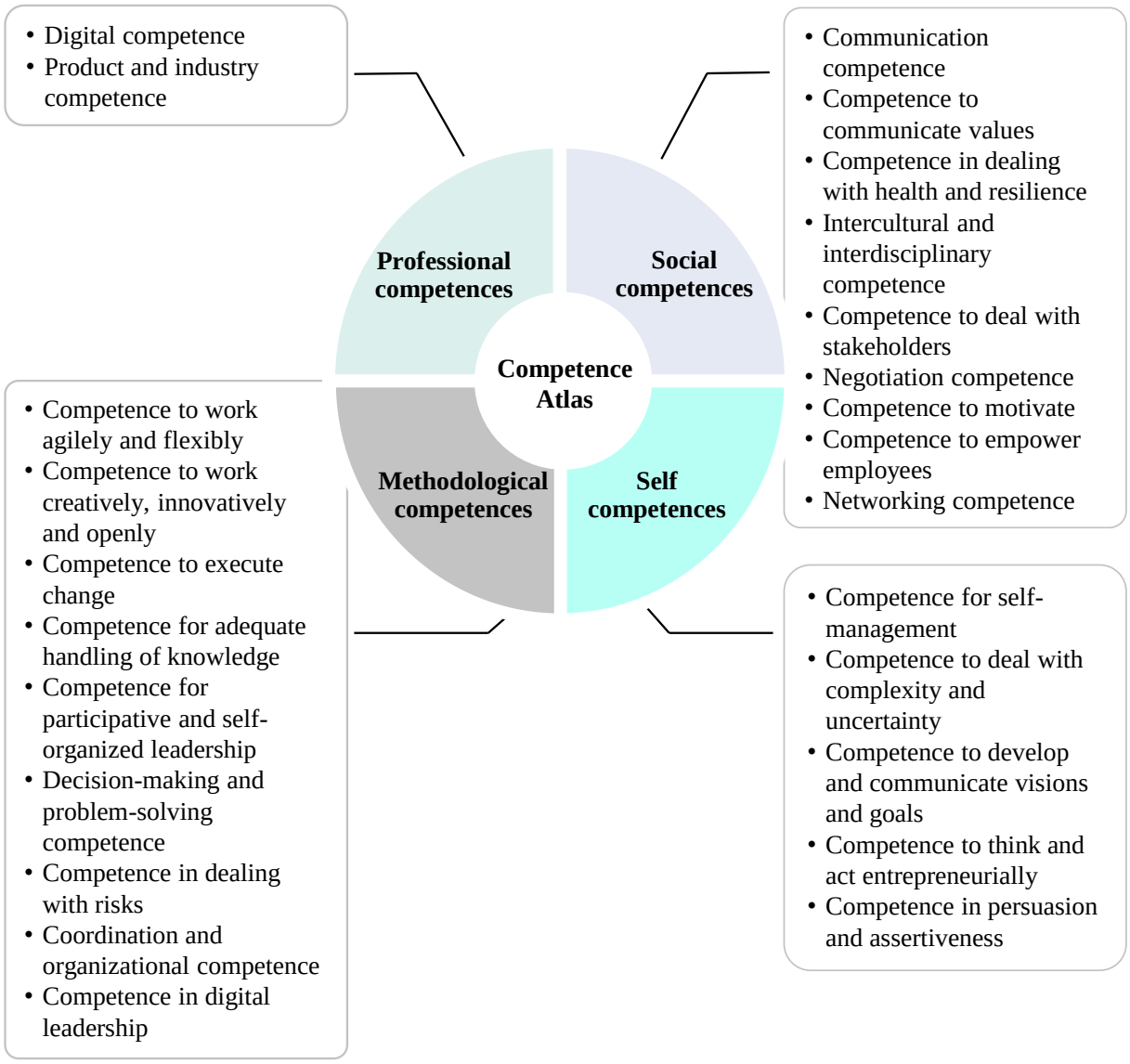

Figure 5. The competence atlas presents 25 areas of competences

Professional competences are understood as specialist knowledge and its application, which are required to master specific tasks (Kopf et al., 2010). This includes digital competence, which is understood as the knowledge of and ability to use digital technologies. It also includes product and industry competence, which varies from one work context to another. Methodological competences include various competences that can be used independently of the respective subject and enable

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complex tasks to be mastered (Kopf et al., 2010). These include, for example, the competence to work creatively, innovatively, and openly. Here, the leader uses creative resources to generate solutions (products, business models, or processes) (Klein, 2020; Shet & Pereira, 2021). A decision-making and problem-solving competence is also part of methodological competences. This refers to the ability to solve problems with the help of analytical and creative methods (Łupicka & Grzybowska, 2018). Under social competence, various competences are presented that are necessary to act appropriately in relationships with fellow human beings (Kopf et al., 2010). These include, for example, communication competence as well as intercultural and interdisciplinary competence. Both serve to be able to master tasks together in a team. Self competence is the ability and willingness to develop oneself and to develop one's talents, motivation, and willingness to perform (Kopf et al., 2010). This includes, for example, the competence for self-management. The leader succeeds in this through good self-organization, time management health-promoting measures, mindfulness, and resilience (Felfe et al., 2014; Klus & Müller, 2019). The competence to think and act entrepreneurially is also understood as self-competence and describes the ability to act in a goal-oriented manner in the interests of the company and to empathize with entrepreneurial processes (Wilk, 2011, p. 128).

5 VALIDATION OF THE COMPETENCE ATLAS THROUGH QUALITATIVE AND QUANTITATIVE ANALYSIS

5.1 Qualitative analysis through expert interviews

In conducting the qualitative interviews, the areas of competences identified in the literature research were validated and extended to include additional areas. Five areas of competences were added, one competence was extended, 22 areas of competences were confirmed by the expert interviews, and three areas of competences were not mentioned in the expert interviews. Figure 6 provides an overview of the results of the expert interviews. The areas of competences "Technical knowledge and system understanding competence", "Competence to use system development tools", "Organizational development competence", "Teamwork competence", and "Competence to act emphatically" were added. Here, technical knowledge and systems understanding competence is to be particularly emphasized. The experts highlighted the need for an understanding of fundamental interconnections in several disciplines and the ability to understand the patterns of the other disciplines as an important competence in Advanced Systems Engineering. In addition, they noted, deep expertise in one area is very important. They must also have a basic understanding of how complex technical systems work, understand how they interact with their environment, and have the knowledge and skills to develop such systems. This also requires the ability to use appropriate tools. With the expert interviews, it was thus possible to close the research gap and to supplement the area of competence with five further aspects that are specifically necessary for Advanced Systems Engineering.

The two competences "Teamwork competence" and "Competence to act emphatically" were disregarded in the literature review because they were considered personality traits. However, since these characteristics were regarded as particularly essential by the experts, they will be considered further in the context of the work.

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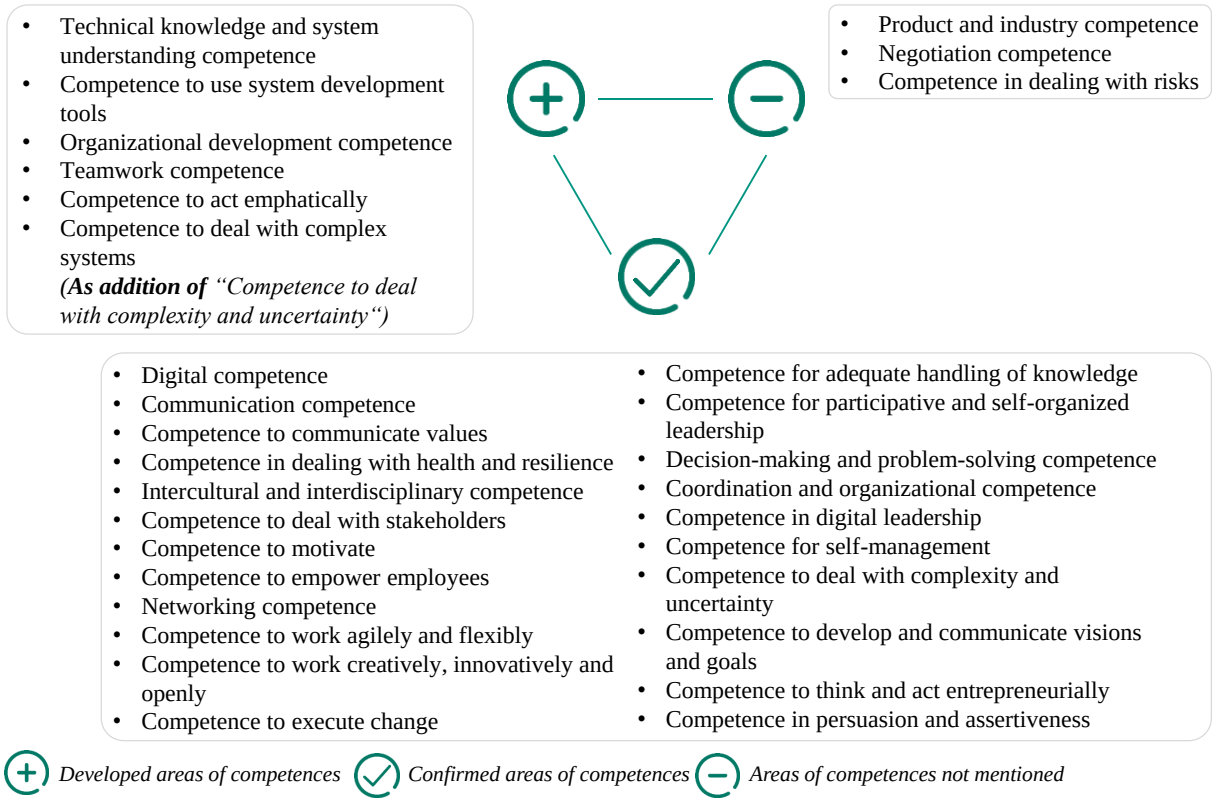

Figure 6. Validation of the areas of competences

5.2 Quantitative analysis through survey

The 30 areas of competences identified by the literature research and the expert interviews were analysed at a quantitative level by a survey. The target group of the survey was prospective leaders with a background in engineering. The participants were asked to rate the future relevance of the respective areas of competences on a Likert scale from 0 (no relevance) to 4 (very high relevance). Figure 7 shows the mean relevance values for the four competence dimensions.

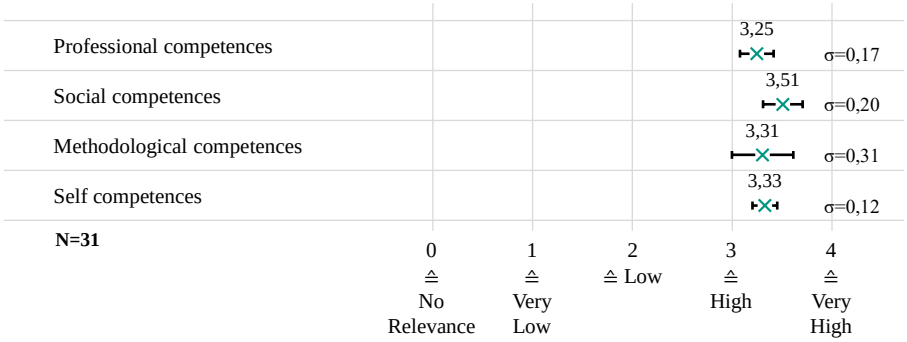

Figure 7. Overview of survey results

The mean relevance scores for the professional competences range from 3.10 (technical knowledge and system understanding competence) to 3.48 for digital competence. The relevance of all professional competences was rated by the respondents at an average of 3.25. For the social competences, the mean scores ranged from 3.26 for intercultural and interdisciplinary competence to 3.87 (communication competence). On average, the social competences were rated at 3.51. This represents the highest mean value of all competence dimensions. The mean scores for the various methodological competences ranged from 2.52 for competence to use system development tools to 3.71 for decision-making and problem-solving competence. The mean scores for the six self competences range from 3.23 (competence to deal with complexity, complex systems, and uncertainty) to 3.60 (competence to think and act entrepreneurially). The mean score for all self competences is 3.33.

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Two important findings stand out. First, the relevance of all competences is high to very high on average (except for competence to use system development tools). In addition, it was found that the standard deviation was very high in many cases, which means that there is a high degree of uncertainty about the relevance of the respective areas of competences. Nevertheless, all areas of competences were taken into further consideration due to the high average ratings.

6 THE COMPETENCE PORTFOLIO FOR FUTURE LEADERS

Based on the results of the survey, a two-dimensional portfolio was developed. On the horizontal axis, it is divided into areas of competence that are generally considered relevant for leaders, areas of competences that are necessary for the context of Advanced Systems Engineering in addition to the generally relevant competences, and areas of competences that are necessary for the implementation of New Work concepts Engineering in addition to the generally relevant competences. On the vertical axis, the areas of competences were subdivided into the three categories of relevant, highly relevant and most relevant. For the subdivision on the horizontal, all areas of competences that can be assigned to these two areas were identified with the help of the characteristics of New Work and ASE from the state of research. For the vertical breakdown, all areas of competences that were rated lower than 2,5 on average in the conducted survey were assigned to *relevant*. Areas of competences with an average rating lower than 3,0 and higher than 2,5 were assigned to *highly relevant* and all areas of competences with an average of 3,0 or higher were assigned to *most relevant*. The developed competence portfolio is shown in Figure 8. A total of eight and nine areas of competences were identified, respectively, which are directly related to the changed requirements resulting from ASE and New Work. It is also striking in Figure 8 that the competence in digital leadership is rated as having only a medium relevance in the future. One attempt at an explanation is that many people already take this competence for granted due to the developments during the Corona pandemic. As already mentioned in chapter 5, the relevance of social competences is considered to most relevant. This is also evident in Figure 8, where a large number of areas of competences that can be assigned to social competences are shown in the category of most relevant in the future.

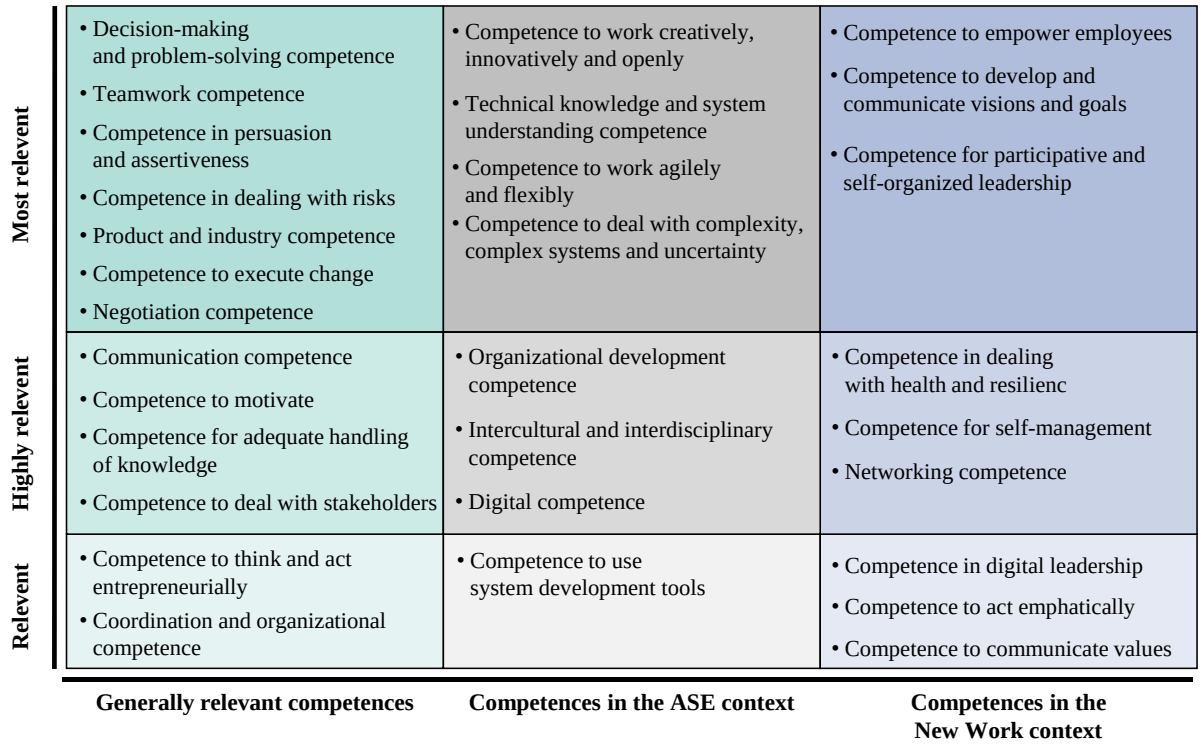

Figure 8. The competence portfolio for future leaders

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7 CONCLUSION, DISCUSSION AND OUTLOOK

The shift towards the development of Advanced Systems and the resulting increase in complexity in the development process requires new ways of working. The Advanced Systems Engineering mission statement unites approaches that place developers at the centre of product development more than ever. The concept of New Work embraces some of the central aspects addressed by ASE and can therefore be seen as an important concept for the successful implementation of Advanced Engineering. This change in the ways of working demands new competences of leaders to successfully enable teams in the development of Advanced Systems. The goal of this work was to present an overview of the competences that future leaders will need in the development of Advanced Systems and against the background of New Work. The already profoundly discussed competences from other literature could complemented with a total of four newly developed competences for leaders that are specifically relevant in the development of Advanced Systems. The developed competence portfolio presents relevant competences for future leaders in the development of Advanced Systems. In the development of the competence portfolio, some aspects could be identified that require more detailed consideration. First, the amount of competences that could be found in the literature including the very different terms called for a standardization. In this unification, key aspects may have been cut. Second, in the expert interviews, the experts emphasized different dimensions of competences depending on their personal background. It is apparent here that if the background was technical, the professional and methodological competences were particularly emphasized. If the technical background was missing, the focus of the statements was on social and personal factors. Thirdly, while for some areas of competence the survey clearly stated that these will be very relevant in the future, because of a low standard deviation, the participants in the survey disagreed strongly on some areas of competence as e.g. the competence to motivate. This hardens the statement of the expert interviews that the evaluation was dependent on personal background. Fourth, some of the competences were rated with unexpectedly low relevance. For example, the competence to deal with risks is addressed as important in the literature. Nevertheless, the experts did not describe risk management as a relevant competence. In their view, risk management is a self-evident skill. Nevertheless, the results of this work thus provide the basis for enabling leaders to work successfully in ASE by presenting a portfolio of relevant competences for future leaders in the development of Advanced Systems and against the background of New Work. Following this research, future leaders can plan their skill development activities in a targeted manner. For industry, based on the competence portfolio individual training opportunities can be designed to focus on continuous employee development.

REFERENCES

Albers, A. (2010). Five Hypotheses about Engineering Processes and their Consequences. In I. Horvath, F. Mandorli, & Z. Rusak (Chairs), *TMCE Symposium*, Ancona, Italien.

Albers, A., Dumitrescu, R., Gausemeier, J., & Riedel, O. (2022). *Advanced Systems Engineering: Eine neue Perspektive für die Wertschöpfung von morgen*. www.advanced-systems-engineering.de

Bergmann, F. (2019). *New work, new culture: Work we want and a culture that strengthens us*. Zero Books.

Bundesministerium für Bildung und Forschung. (2022, May 13). *Deutscher Qualifikationsrahmen: Glossar*. https://www.dqr.de/dqr/de/der-dqr/glossar/glossar_node.html#Kompetenz

Cattell, R. B. (1966). The Scree Test For The Number Of Factors. *Multivariate Behavioral Research*, *1*(2), 245–276. https://doi.org/10.1207/s15327906mbr0102_10

Dumitrescu, R., Albers, A., Riedel, O., Stark, R., & Gausemeier, J. (Eds.). (2021). *Advanced Systems Engineering: Value Creation in Transition*. Engineering in Germany - Status Quo in Business and Science. Paderborn.

Erpenbeck, J. (2010). Vereinfachung durch Komplexität: Persönlichkeitseigenschaften und Kompetenzen. *Sitzungsberichte Der Leibniz-Sozietät Der Wissenschaften Zu Berlin*, *108*, 79–91.

Felfe, J., Ducki, A., & Franke, F. (2014). Führungskompetenzen der Zukunft. In B. Badura, A. Ducki, H. Schröder, J. Klose, & M. Meyer (Eds.), *Fehlzeiten-Report* 2014 (pp. 139–148). Springer. https://doi.org/10.1007/978-3-662-43531-1_14

Grote, E.-M., Pfeifer, S. A., Roltgen, D., Kuhn, A., & Dumitrescu, R. (2020). Towards Defining Role Models in Advanced Systems Engineering. In *Proceedings of the 6th IEEE International Symposium on Systems Engineering (ISSE)* (pp. 1–7). IEEE. https://doi.org/10.1109/ISSE49799.2020.9272225

Hitchins, D. K. (2003). *Advanced systems thinking, engineering, and management*. Artech House.

Hofman, J., Piele, A., & Piele, C. (2019). *New Work: Best Practices und Zukunftsmodelle*. Fraunhofer-Institut für Arbeitswirtschaft und Organisation (IAO).

https://doi.org/10.1017/pds.2023.8 Published online by Cambridge University Press

Isermann, R. (2008). *Mechatronische Systeme* (2nd ed.). Springer.
Keating, C., Rogers, R., Unal, R., Dryer, D., Sousa-Poza, A., Safford, R., Peterson, W., & Rabadi, G. (2003). System of Systems Engineering. *Engineering Management Journal*, *15*(3), 36–45. https://doi.org/10.1080/10429247.2003.11415214
Klein, M. (2020). Leadership Characteristics in the Era of Digital Transformation. *Business & Management Studies*, *8*(1), 883–902. https://doi.org/10.15295/bmij.v8i1.1441
Klus, M. F., & Müller, J. (2019). The digital leader: What one needs to master today's organisational challenges. *Diskussionspapier Des Instituts Für Organisationsökonomik*(11). https://doi.org/10419/213440
Kopf, M., Leipold, J., & Seidl, T. (2010). Kompetenzen in Lehrveranstaltungen und Prüfungen: Handreichung für Lehrende. *Mainzer Beiträge Zur Hochschulentwicklung*, *16*.
Łupicka, A., & Grzybowska, K. (2018). Key Managerial Competencies for Industry 4.0: Practitioners', Researchers' and Students'Opinions. *Logistics and Transport*, *39*(3), 39–46. https://doi.org/10.26411/83-1734-2015-3-39-4-18
Millar, C. C. J. M., Groth, O., & Mahon, J. F. (2018). Management Innovation in a VUCA World: Challenges and Recommendations. *California Management Review*, *61*(1), 5–14. https://doi.org/10.1177/0008125618805111
North, K., Reinhardt, K., & Sieber-Suter, B. (2013). Was ist Kompetenz? In K. North, K. Reinhardt, & B. Sieber-Suter (Eds.), *Kompetenzmanagement in der Praxis* (2nd ed., pp. 43–91). Gabler. https://doi.org/10.1007/978-3-8349-3696-7_2
Peters, P., Dulk, L. den, & van der Lippe, T. (2009). The effects of time-spatial flexibility and new working conditions on employees' work–life balance: the Dutch case. *Community, Work & Family*, *12*(3), 279–297. https://doi.org/10.1080/13668800902968907
Ropohl, G. (2009). *Allgemeine Technologie: Eine Systemtheorie der Technik* (3rd ed.). Universitätsverlag Karlsruhe.
Sage, A. P., & Rouse, W. B. (2009). *Handbook of systems engineering and management* (2nd ed.). *Wiley series in systems engineering and management*. John Wiley & Sons.
Savić, D. (2020). COVID-19 and work from home: Digital transformation of the workforce. *The Grey Journal*, *16*(2), 101–104.
Shet, S. V., & Pereira, V. (2021). Proposed managerial competencies for Industry 4.0: Implications for social sustainability. *Technological Forecasting and Social Change*, *173*. https://doi.org/10.1016/j.techfore.2021.121080
Venkatesh, N. (2020). Leadership 4.0: Leadership Strategies for Industry 4.0. *Solid State Technology*, *63*(6), 2709–2713.
Von Au, C. (2020). New Leadership: Führungspersönlichkeiten im digitalen Zeitalter. In M. Harwardt, P. F.-J. Niermann, A. M. Schmutte, & A. Steuernagel (Eds.), *Führen und Managen in der digitalen Transformation: Trends, Best Practices und Herausforderungen* (pp. 99–113). Springer Fachmedien; Springer Gabler.
Wilk, G. (2011). *Stellenbeschreibungen und Anforderungsprofile*. *Haufe-Praxisratgeber*. Haufe-Lexware.
Wirtz, M. A. (Ed.). (2020). *Dorsch-Lexikon der Psychologie* (19th ed.). Hogrefe.

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