

THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

# Skilling Them Softly

Bridging Skill Gaps For The Future Industrial Workforce

GRETA BRAUN



Department of Industrial and Materials Science

CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2026

Skilling Them Softly  
Bridging Skill Gaps for the Future Industrial  
Workforce  
GRETA BRAUN  
ISBN 978-91-8103-355-7

© GRETA RBAUN, 2026

Doktorsavhandlingar vid Chalmers tekniska högskola  
Ny serie nr. 5812  
ISSN 0346-718X

Department of Industrial and Materials Science  
Chalmers University of Technology  
SE-412 96 Gothenburg  
Sweden  
Telephone + 46 0 31-772 1000

Cover:  
Original painting by Vera Braun.  
The image symbolises the challenge in bridging  
skill gaps by jumping across the divide between  
two rocks.

Printed by  
Chalmers digitaltryck  
Gothenburg, Sweden 2026

# ABSTRACT

Industries are facing rapidly evolving skill needs, driven by technological transformations, the climate crisis, and geopolitical threats. This leads to widening skill gaps, which are complex to understand and involve multiple stakeholders, including employees, employers, education providers, and policymakers. Bridging these skill gaps requires not only technical solutions but also strategic organisational practices and motivation.

This research aimed to propose ways to bridge these skill gaps by incorporating stakeholders' diverse perspectives. To pursue this mission, Design Research Methodology was applied in four steps: understanding the problem and formulating the research goal, exploring stakeholders' needs, proposing a solution to the problem, and evaluating this solution.

The findings of the studies in this research are presented in seven appended papers. The results include a definition of skill gaps, a description of the main stakeholders involved, and a deeper understanding of learners' motivational needs. Moreover, this thesis provides insights into managerial practices and challenges in bridging skill gaps within organisations. Additionally, the results highlight companies' workforce readiness towards Industry 5.0, regarding skills, upskilling initiatives, and workforce resilience. Lastly, the thesis proposes and evaluates a solution for personalised skill matching that recommends learning opportunities to employees based on their skill gaps.

The contribution of this thesis extends over three main dimensions: theoretical, practical, and societal. Theoretically, it improves understanding of skill gaps and identifies both individual needs and organisational practices. In practice, it provides guidelines for designing motivational learning, a framework for developing organisational practices to address skill gaps, and policy recommendations for targeted skill development aligned with Industry 5.0. The research also offers practical insights into platforms for managing skill gaps and highlights challenges and practices encountered during implementation. Societally, it underscores essential ways to prevent unemployment and enhance people's well-being.

**Keywords:** Skill; Skill gap; Competence; Future of Work; Human Resources Management; Industry; Industry 5.0; Upskilling.



# ACKNOWLEDGEMENTS

Reflecting his belief in living each day with purpose and lifelong self-development, Mahatma Gandhi said: “Live as if you would die tomorrow, learn as if you would live forever”. In a world of constant change, lifelong learning is, or should be, part of our daily routines. We become who we surround ourselves with. Thanks to the smart people in my life, I have been lucky enough to learn continuously.

I would like to begin by thanking my supervisor, Professor Johan Stahre. Words cannot express how grateful I am for the opportunity to start this joyful and interesting PhD journey. With your positive and visionary attitude, you inspire me to bring out the best in every situation and to develop my qualities as a researcher and as a human being. You also helped me build my confidence and believe in myself. Thanks for being such a supportive supervisor and friend!

Next, I would like to thank my second supervisor, Professor Anna Syberfeldt, who consistently encouraged me during busy periods, helped me find structure, and taught me to say “no” at the “right” moments. Thank you for helping me to focus! A special thanks to my second supervisor, Professor Raija Hämäläinen, who guided me from Finland and provided crucial perspectives, especially on research methodology and pedagogical aspects. Thank you for building the collaboration between our teams. It was an excellent opportunity to collaborate with Pauliina Rikala, Paavo Rätty, and Miitta Järvinen.

A big thank you to the fantastic Ingenjör4.0 team – Professor Bengt-Göran Rosén, Licentiate Mattias Bokinge, and Hanna Widell. From the first day I started my PhD, I felt so welcome and heard, and our Friday meetings always put a smile on my face. It is an absolute pleasure to work together on this important initiative.

Thank you, Professor Björn Johansson, for your encouragement and optimism. To Professor Anders Skoogh, Associate Professor Mélanie Despeisse, Senior Lecturer Ebru Turanoglu Bekar, and Assistant Professor Jon Bokrantz – thank you for your ideas, guidance, and inspiration. A special thanks to Dr Clarissa, my “work wife” and hermana - you always bring me peace and laughter. Thank you for coming into my life and transforming small things like supermarket strolls into the funniest Sunday activity. You just make my life so much better! Thank you also for helping me get through tough paper reviews. Thank you, Huizhong, for sharing the dream of a human-centric industry, and for always taking care of the people around you and me. Thank you, my data geeks, Mohan and Erika, for helping me with data analytics. I’m grateful to Martin for our great teamwork in the Chalmers Upskilling Academy. Moreover, I’m extremely happy to have such amazing Production Systems colleagues whom I can always count on for help, an afterwork, or a good laugh. Thank you to Dr Omkar, Dr Arpita, Lic Tina, Lic Hao, Lic Henrik, Sandra, Sven, Silvan, Lic Siyuan, Johanna, Anna-Jonna, Elisa, Magnus, Lic Qi, Dr Zeyneb, Anita, and Ellinor. Thank you, Agnes, for making work and life so much easier and fun that summer. Thanks to Assistant Professor Marta Pinzone, who has been an amazing partner on skills-related projects. Thank you, Marta, for being a safe space in

the academic environment and inspiring me! Thank you, Professor David Romero, for many fun conferences and your visits to Chalmersland. I would like to thank Docent Lars-Ola Bligård for equipping me with research skills and providing guidance in key methodological questions.

I'm extremely grateful to all the people who have contributed their time and insights to the empirical data for my studies. Thanks to your expertise, my work became impactful.

Finally, I want to thank my family and friends. Without you, I wouldn't be where I am today. Mum & Dad, thank you for giving me everything you could and for letting me thrive in this world. Thank you for reminding me to take a break and relax. Thank you for empowering me, as a kid, to "dare" to ask a friend for a playdate or start a new sport, and for telling me today that I can do everything I want. You have taught me to ask myself first whether I'm proud before asking someone else. Thank you, Vera, the best sister in the world. You show me how to be compassionate with myself and prioritise my needs. I'm thankful to have you through the tough times, as well as the beautiful and fun times. You have a talent for always making me laugh and for illustrating my thoughts with beautiful pictures and visualisations. Thank you to my aunt Sandra for hours of deep talks and spontaneous dances. Thank you to my Swedish family - Klara, Jonatan, Jens, Morfar, Mormor & Sven, Carina, and Martin, for being my warm and beautiful home, always with the door open for me. Special thanks to Nachon, who made my licentiate celebration a Vogue-like Japanese dream dinner. And Nadine, thank you for putting your magic into some of my texts. Thank you, Raffi, for helping me make PowerPoint slides more beautiful. Thank you, Kevin, for being my calm anchor. Thank you to my amazing friends, who balanced the PhD years by being there for me, inviting me on adventures, or sharing a meal. I am grateful for all the fun we had over the years, whether in Germany, Sweden, or out and about. You are the place where I feel loved and happy.

*Greta Braun  
Gothenburg, February 2026*

# LIST OF APPENDED PAPERS

The seven appended papers in this thesis are listed here, along with the contributions and distribution of work among the authors.

## **Paper I Understanding and Measuring Skill Gaps in Industry 4.0 — A Review.**

**P. Rikala, G. Braun, M. Järvinen, J. Stahre and R. Hämäläinen (2024)**

Published in *Technological Forecasting and Social Change* 2024 Vol. 201.

Distribution of work. Pauliina Rikala: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review & editing. Greta Braun: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review & editing. Miitta Järvinen: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review & editing. Johan Stahre: Conceptualisation, Funding acquisition, Supervision, Writing – original draft, Writing – review & editing. Raija Hämäläinen: Conceptualisation, Supervision, Writing – original draft, Writing – review & editing.

## **Paper II Bridging Skill Gaps – A Systematic Literature Review of Strategies for Industry**

**G. Braun, P. Rikala, M. Järvinen, R. Hämäläinen and J. Stahre**

Presented at the *Conference Swedish Production Symposium*, Trollhättan, April 2024. Published in *Advances in Transdisciplinary Engineering*, vol. 52, pp. 687 - 696.

Distribution of work. Greta Braun: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review & editing. Pauliina Rikala: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review & editing. Miitta Järvinen: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review & editing. Raija Hämäläinen: Conceptualisation, Supervision, Writing – original draft, Writing – review & editing. Johan Stahre: Conceptualisation, Funding acquisition, Supervision, Writing – original draft, Writing – review & editing.

**Paper III Ingejör4.0 – A National Upskilling Programme to Bridge Industry's Skill Gap**

G. Braun, J. Stahre, B.-G. Rosén and M. Bokinge (2023)

Presented at the *CIRP CMS*, Cape Town, October 2023. Published in *Procedia CIRP 2023* Vol. 120 Pages 1286-1291.

Distribution of work. Greta Braun: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review & editing. Johan Stahre: Conceptualisation, Funding acquisition, Supervision, Writing – original draft, Writing – review & editing. Bengt-Göran Rosén: Conceptualisation, Funding acquisition, Writing – review & editing. Mattias Bokinge: Conceptualisation, Formal analysis, Investigation, Visualisation, Writing – original draft, Writing – review & editing.

**Paper IV The Skill Bridge – A Global Qualitative Analysis of Skill Gap Management**

G. Braun, P. Rätty, M. Bokinge, P. Rikala, R. Hämäläinen, A. Syberfeldt, J. Stahre (2025)

Published in *Journal of Environmental Management*, vol. 395

Distribution of work. Greta Braun: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review & editing. Paavo Rätty: Conceptualisation, Formal analysis, Investigation, Methodology, Writing – review & editing. Mattias Bokinge: Conceptualisation, Formal analysis, Investigation, Methodology, Writing – review & editing. Pauliina Rikala: Conceptualisation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. Raija Hämäläinen: Conceptualisation, Supervision, Funding acquisition, Writing – review & editing. Anna Syberfeldt: Conceptualisation, Supervision, Writing – original draft, Writing – review & editing. Johan Stahre: Conceptualisation, Supervision, Funding acquisition, Writing – original draft, Writing – review & editing.

**Paper V Navigating the Human-centric Shift: A Typology of Workforce Readiness for Industry 5.0**

G. Braun, J. Stahre

Manuscript in preparation. In the review process of a scientific journal.

Distribution of work. Greta Braun: Conceptualisation, Funding acquisition, Formal analysis, Investigation, Methodology, Visualisation, Writing –

original draft, Writing – review & editing. Johan Stahre: Conceptualisation, Formal analysis, Supervision, Funding acquisition, Writing – original draft, Writing – review & editing.

#### **Paper VI Mastering Industry’s Skill Gap - Matching Employee Needs with New Learning Challenges**

G. Braun, M. Bokinge, B. G. Rosén, A. Syberfeldt and J. Stahre (2024)

Presented at the *IEEE International Conference on Industrial Engineering and Engineering Management (IEEM) 15-18 Dec. 2024, Bangkok*. Published in *Proceedings, Pages 668-672*.

Distribution of work. Greta Braun: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review & editing. Mattias Bokinge: Conceptualisation, Formal analysis, Investigation, Visualisation, Writing – original draft, Writing – review & editing. Bengt-Göran Rosén: Conceptualisation, Funding acquisition, Writing – review & editing. Johan Stahre: Conceptualisation, Funding acquisition, Supervision, Writing – review & editing.

#### **Paper VII Evaluating a Skill Management Platform – Towards an Upskilling System for Large and Small Companies**

G. Braun, M. Kretschmer, M. Bokinge, K. Singer-Coudoux, B.-G. Rosén, J. Stahre (2025)

Presented at the *European Conference on E-Learning, Copenhagen, October 2025*. Published in *European Conference on e-Learning Vol. 24, Pages 21-29*.

Distribution of work. Greta Braun: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review & editing. Maria Kretschmer: Conceptualisation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. Mattias Bokinge: Conceptualisation, Formal analysis, Investigation. Katrin Singer-Coudoux: Conceptualisation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. Bengt-Göran Rosén: Conceptualisation, Funding acquisition, Writing – review & editing. Johan Stahre: Conceptualisation, Funding acquisition, Supervision, Writing – review & editing.



# LIST OF ADDITIONAL PAPERS

This list of additional papers includes related work, important for the content of this thesis but outside of the scope for answering the research questions.

**Paper 1**    **Managing Change towards the Future of Work - Clustering Key Perspectives**

Katrin Singer-Coudoux, Greta Braun, and Johan Stahre (2023)

Presented at APMS 2023, Trondheim, Norway.

Published in *IFIP Advances in Information and Communication Technology*, vol 689. Springer, Cham.

**Paper 2**    **Motivational Challenges of Engineers Participating in an Online Upskilling Program**

Greta Braun, Miitta Järvinen, Johan Stahre, Raija Hämäläinen (2022)

Presented at the *European Conference on e-Learning*, Brighton, 26-28 October 2022.

Published in *Proceedings of the 21<sup>st</sup> European Conference on e-Learning*, vol. 21, no. 1.

**Paper 3**    **Skills Matching for a Greener Industry 4.0 – a Literature Review**

Greta Braun, Johan Stahre, and Raija Hämäläinen

Presented at the *Swedish Production Symposium*, Skövde, 26-29 April 2022.  
Published in *Advances in Transdisciplinary Engineering. Vol 21*, p. 677 - 688.

**Paper 4**    **Battery production systems: state of the art and future developments**

Mélanie Despeisse, Björn Johansson, Jon Bokrantz, Greta Braun, Arpita Chari, Xiaoxia Chen, Qi Fang, Clarissa A. González Chávez, Anders Skoogh, Johan Stahre, Ninan Theradapuzha Mathew, Ebru Turanoglu Bekar, Hao Wang, Roland Örtengren (2023)

APMS 2023, Trondheim, Norway.

*IFIP Advances in Information and Communication Technology*, vol 692. Springer, Cham. In: Alfnes, E., Romsdal, A., Strandhagen, J.O., von Cieminski,

G., Romero, D. (eds) *Advances in Production Management Systems. Production Management Systems for Responsible Manufacturing, Service, and Logistics Futures.*

**Paper 5 Contemporary and Future Manufacturing -  
Unveiling the Skills Palette for Thriving in  
Industry 5.0.**

Marta Pinzone, Greta Braun, Johan Stahre (2024).

APMS 2024, Chemnitz, Germany.

IFIP *Advances in Information and Communication Technology*, vol 729. Springer, Cham. In: Thüerer, M., Riedel, R., von Cieminski, G., Romero, D. (eds) *Advances in Production Management Systems. Production Management Systems for Volatile, Uncertain, Complex, and Ambiguous Environments.*

# TABLE OF CONTENTS

1	INTRODUCTION .....	1
1.1	Background .....	2
1.2	Aim and Research Questions .....	3
1.3	Scope and Delimitations .....	4
1.4	Outline of the Thesis .....	5
2	FRAME OF REFERENCE.....	7
2.1	Industrial advancements and work transformation .....	8
2.2	Skill gaps.....	10
2.3	Strategies to bridge skill gaps.....	11
3	METHODOLOGICAL APPROACH .....	17
3.1	Author’s Background and Worldview .....	18
3.2	Research Design .....	18
4	RESULTS.....	25
4.1	Understanding the skill gap problem.....	26
4.2	Current practices .....	27
4.3	Prescribing a tool.....	33
4.4	Evaluation .....	35
5	DISCUSSION.....	41
5.1	Positioning the thesis in relation to previous work.....	42
5.2	Discussing the research questions.....	43
5.3	Contribution .....	48
5.4	Methodological Reflections .....	49
5.5	Future research.....	51
6	CONCLUSION.....	53

PAPER I

PAPER II

PAPER III

PAPER IV

PAPER V

PAPER VI

PAPER VII

# LIST OF FIGURES

FIGURE 1 - DRM APPLIED TO THIS WORK (ADOPTED FROM BLESSING AND CHAKRABARTI (2009)).....	19
FIGURE 2 - STAKEHOLDERS IN BRIDGING SKILL GAPS (BRAUN ET AL., 2024B) .....	27
FIGURE 3 - THE SKILL BRIDGE (BRAUN ET AL., 2025B) .....	28
FIGURE 4 - FROM SKILLS TO EUROPEAN COMPETITIVENESS (FROM PAPER V) .....	31
FIGURE 5 – THREE COMPANY CLUSTERS CHARACTERISED BY SKILLS, UPSKILLING, AND WORKFORCE RESILIENCE (PAPER V).....	32
FIGURE 6 - IDENTIFYING SKILL NEEDS (BRAUN ET AL., 2024A) .....	34
FIGURE 7 - CONCEPT BEHIND SKILL-MANAGEMENT PLATFORM (BRAUN ET AL., 2024A).....	34
FIGURE 8 - LEARNING PATH PRESENTED IN USER DASHBOARD (BRAUN ET AL., 2024A) .....	35
FIGURE 9 - BUILDING A SCALABLE SKILL MANAGEMENT SYSTEM (BRAUN ET AL., 2025A) .....	36

# LIST OF TABLES

TABLE 1 - RESEARCH ACTIVITIES AND THEIR ALIGNMENT WITH THE APPENDED PAPERS. ....	20
TABLE 2 - PRACTICES AND CHALLENGES ACROSS THE FIVE THEMES (BRAUN ET AL., 2025B) .....	30
TABLE 3 - SUMMARY OF THE MAIN CONTRIBUTIONS FROM THE APPENDED PAPERS. ....	38

# LIST OF ABBREVIATIONS

AI – Artificial Intelligence

DRM – Design Research Methodology

ESCO – European Skills, Competences, Qualifications, and Occupations

HR – Human Resources

KPI – Key Performance Indicator

L&D – Learning and Development

LMS – Learning Management System

MOOC – Massive open online course

SME – Small and medium-sized enterprises

STEM – Science, Technology, Engineering, Mathematics

US – United States

# 1

## INTRODUCTION

*AI will not take your job. People who use AI will.*

- *Collective insight*

Chapter 1 presents the background to the problem under study in this thesis. Next, the research aim is outlined, and the research questions are defined. To clarify the scope and delimitations of this work, these are presented.

## 1.1 BACKGROUND

In today's industrial landscape, a shortage of skilled talent fuels prolonged, unresolved political debates. Organisations face one of their most significant challenges: finding and retaining employees with the skills needed to sustain their market position and expand their business (ManPowerGroup, 2024). This becomes increasingly difficult in a complex, rapidly evolving industry where workplaces transform swiftly (Smil, 2021). 75% of employers worldwide report difficulties in hiring skilled talent (ManPowerGroup, 2024). Companies seek employees with analytical skills, critical thinking, lifelong learning, problem-solving, Artificial Intelligence (AI) literacy, and emotional intelligence, among other highly sought-after traits (World Economic Forum, 2025). These skills are essential for remaining competitive and realising new business goals related to sustainability, resilience, and digitalisation. The recent report to the European Commission by former Italian Prime Minister M. Draghi strongly highlights the importance of skilled talent in maintaining Europe's competitiveness (Draghi, 2024). The lack of adequately skilled personnel hampers companies' ability to achieve the productivity gains promised by new technologies. This issue is particularly evident when implementing new sustainable, service-based business models (González Chávez et al., 2023), adopting smart maintenance practices (Bokrantz et al., 2020), advancing critical AI solutions (Rajashekarappa et al., 2025), or developing additive manufacturing (Stavropoulos et al., 2023).

Meanwhile, employees worldwide are concerned with the same inquiry: "Will AI take my job?". The answer to that question is not simple, nor is the endeavour to redefine employment in the age of AI. According to the World Economic Forum's extensive study of 1000 employers on the Future of Jobs, 92 million jobs are expected to be displaced globally. However, around 170 million new roles are expected to be created (World Economic Forum, 2025). Hence, more jobs are created than lost. This means people will have to transition between jobs. The data underscores the importance of continuous skills development, as individuals transitioning to new jobs will require significant reskilling. By 2030, 39% of people's skills are expected to change (World Economic Forum, 2025).

Historically, labour shortages have hindered industrial transformation. Often called the productivity paradox, past industrial revolutions saw new technologies initially cause productivity Key Performance Indicators (KPI) to decline rather than grow, as workers lacked the skills to maximise the value of these technologies (Brynjolfsson et al., 2020). For example, after the introduction of technologies during the First Industrial Revolution, wages stagnated despite industrial innovation. Following the Second Industrial Revolution, characterised by electrification, it took a long time for the new technology to deliver benefits (Brynjolfsson et al., 2020). Only when intangibles such as the skills required to use these new technologies were in place did productivity increase; as a result, productivity follows a J-curve pattern (Brynjolfsson et al., 2020). The recent rise of AI shows a similar pattern. The difference is that, with the introduction of AI technologies, such as AI agents, not only do low-skilled workers increase the quality and productivity of their work, but high-skilled workers do as well, though to a lesser extent (Brynjolfsson et al., 2023).

Recruiting this essential talent is difficult, as demographic trends indicate a decline among younger generations in Europe, the United States (US), and China (European Commission, 2020). Upskilling the existing workforce is vital and may be one of the most critical actions required of today's industrial leaders. Upskilling—equipping employees with the skills to add value to their roles and perform their tasks—is increasingly promoted by both government initiatives and companies. More companies are committing to upskilling initiatives as they recognise the need to equip their workforce with the necessary skills. There is currently a lack of data and evidence on best practices and the return on investment of upskilling efforts to date. This strategic blind spot could mislead future actions. Therefore, there is a strong need not only to increase upskilling efforts but also to improve the accuracy of measuring their impact in industry (World Economic Forum, 2019).

### **Identified Research Gap**

The industrial skills gap is an urgent issue that poses considerable challenges for companies seeking to remain competitive. Failing to address this gap limits potential for business growth and industrial success, which can lead to societal instability, such as higher unemployment. Companies that do not recognise the seriousness of skill gaps and their consequences will find it harder to boost their competitiveness. At a broader societal level, this can cause economic stagnation, hinder progress toward climate goals, and create difficulties with organisational resilience and the prevention of disruptions from geopolitical threats.

Employers, employees, education providers, and governments lack a shared understanding of skill gaps, the factors that influence them, effective methods for assessing their extent, and strategies for closing them. Beyond the absence of a common understanding, attempts to define these gaps are scattered across the literature, resulting in a lack of conceptual agreement. There is unclear guidance on how to accurately assess individual skill gaps, manage them within industrial companies, or address skill development from a policy perspective. In summary, there is an urgent need to develop a clear definition of skill gaps and to learn how to close them; achieving these goals is a vital step in helping practitioners develop effective strategies to bridge and mitigate them.

## **1.2 AIM AND RESEARCH QUESTIONS**

This thesis stemmed from the vision of a skilled industry that leverages technologies to achieve a resilient and sustainable future. In the envisioned industry, human needs are at the centre. This vision of industry provides equal opportunities to everyone and empowers people with the right skills to thrive in their roles. There are no significant skill gaps, since lifelong learning is integrated with daily work life. Ultimately, skill gaps are kept to a minimum and bridged in small steps through lifelong learning.

Consequently, my mission is to address skill gaps arising in industrial contexts and equip employees with the skills needed to remain valuable during industrial transformation. Firstly, the objective is to understand the concept of skill gaps, their underlying causes, and the relationships among stakeholders' skill gaps. Secondly, it seeks to identify

effective methods for measuring skills gaps. Finally, with knowledge of skill gaps and their assessment, the goal is to bridge these gaps. This involves exploring strategies companies can use to address skill shortfalls and testing a skill-matching solution. To guide this work, the following research questions were defined.

The first research question clarifies the concept of skill gaps in the industrial context.

**RQ1: What is a skill gap in the industrial context?**

To address skill gaps, it is essential to first understand their scope. Consequently, measuring or assessing these gaps is crucial and introduces the second research question.

**RQ2: How can skill gaps be measured?**

Bridging skill gaps requires collaboration among multiple stakeholders. The third research question directs the study toward identifying strategies to ultimately close these skill gaps.

**RQ3: How can skill gaps be bridged?**

### 1.3 SCOPE AND DELIMITATIONS

This research focuses on the human-centric perspective within industry. Specifically, it examines how work evolves for high-skilled workers in industry, which new skills are becoming essential for them to acquire, and how they can be supported through this transition. The datasets in this research primarily originate from Swedish, Finnish, and German contexts but also encompass a broader European and global perspective. The studies include large companies, small and medium-sized enterprises [SME], and startups to offer a diverse view of stakeholders' needs. The main aim has been to upskill high-skilled individuals, such as engineers, because these roles significantly influence the competitiveness of industry.

The focus of this work:

- Understanding practices and challenges when upskilling high-skilled professionals, such as engineers or people with an engineering-related background in the manufacturing sector,
- Learners from Swedish or German industrial companies,
- Managers from industrial companies across the world,
- Skills related to Industry 4.0 and Industry 5.0.

Not the focus of this work:

- Understanding how to improve the pipeline to get more young people to choose Science, Technology, Engineering, Mathematics (STEM) studies,
- Understanding how to improve recruitment or employer branding to fill open vacancies,
- Traditional work sciences, including macro-economic analyses,
- Longitudinal educational studies.

## 1.4 OUTLINE OF THE THESIS

After this first chapter, which introduces the importance of this research, the thesis is structured into five chapters.

**Chapter 2, Frame of Reference**, introduces the key terms and theories underpinning the work presented in this thesis. These are organised around technological advancements, work transformation, skill gaps, and strategies to address them, as identified by the stakeholders involved.

**Chapter 3, Methodological Approach**, explores the author's background and worldview and how they influence their choice of research approach. This chapter describes the ontology, epistemology, and methodology, as well as the specific methods used in the studies.

**Chapter 4, Results**, summarises the findings from the seven appended papers, organised according to the methodology's four steps.

**Chapter 5, Discussion**, synthesises all previous chapters to position this thesis in relation to earlier work, provides clear answers to each of the three research questions, explores the contributions to theory, practice, and society, and discusses the methodological approach. Finally, this chapter offers an outlook on necessary future research.

**Chapter 6, Conclusion**, summarises the main ideas of this thesis and concludes it.



# 2

## FRAME OF REFERENCE

*Technology alone will not determine the future of work.*

*The investments we make now in skills, talent systems and human-AI collaboration will shape whether AI becomes a force for shared prosperity or deeper fragmentation.*

*Saadia Zahidi, World Economic Forum*

This chapter begins by describing past and ongoing industrial transformations and their impact on work. Furthermore, research on skill gaps and strategies to bridge them is detailed.

## 2.1 INDUSTRIAL ADVANCEMENTS AND WORK TRANSFORMATION

In the current global landscape, shaped by geopolitical threats, pandemics, and the climate crisis, industries must adapt to survive (Chari et al., 2024). The defence sector is growing, and agile production is vital to meet emerging market demands. Companies are also required to report on sustainability KPIs and are compelled to address their environmental impact. Simultaneously, demographic tipping points are near, and the shortage of young talent will soon become even more apparent. The only continent with high fertility rates is Africa, providing a young workforce for the future (World Manufacturing Foundation, 2024).

Access to a resilient workforce and education should be a key competitive advantage for Europe, according to the European Round Table for Industry (ERT), a network of company leaders from some of Europe's largest companies (European Round Table for Industry, 2024). In response, the European Commission recognised the need to shift the industry's focus. Under the name Industry 5.0, the aim is to build a human-centric, resilient, and sustainable industry (Breque et al., 2021, Leng et al., 2022). The European Commission has consequently launched an Industry 5.0 Community of Practice, which unites companies, universities, and organisations to promote progress towards this new vision (European Commission), in which workforce upskilling is a key component. In March 2025, the European Commission launched the Union of Skills, supporting the resilience of human capital in Europe by incentivising high-level skills, upskilling, and reskilling programmes (European Commission, 2025b).

Throughout the past industrial revolutions, technologies have significantly influenced work and altered the value humans contribute – from the steam engine and mass production to computerisation and digitalisation – leading to productivity improvements and greater welfare, but with uneven effects on worker well-being. Historically, workers have often felt threatened by new technologies and automation. In their study, Frey and Osborne (2013) found that 47% of US employment was at high risk of computerisation. However, they also found that employees with higher levels of education and wages had a lower probability of their tasks being automated. A more recent study predicts that up to 30% of work hours could be automated through generative AI (McKinsey Global Institute, 2024).

In contrast, Autor (2015) highlights a key paradox in the debate: although technologies and innovation have always aimed to reduce human labour, they haven't led to overall job loss. On the contrary, unemployment rates have generally declined in Europe and the US, revealing that automation has also created new jobs. Autor (2015) further pointed out that machines are particularly well-suited to handling routine tasks while humans are suited for tasks in which problem-solving, adaptability, and creativity are needed.

The World Economic Forum regularly conducts studies to compile the Future of Jobs report, which draws on extensive data from companies worldwide to highlight macro-level trends affecting global employment. In its 2025 report, the World Economic Forum states that despite 92 million roles being displaced, there will be an overall increase of 78 million jobs, indicating that more jobs are created than lost (World Economic Forum,

2025). Employers estimate that 39% of key skills will change by 2030. This figure has decreased since the 2023 report, in which surveyed employers estimated that 44% of critical skills for the job market would change. This decline could potentially be due to an increased commitment to upskilling programmes. Over the years, a comparison shows that, for instance, more companies invested in training and upskilling programmes in 2025 compared to 2023 (World Economic Forum, 2023, World Economic Forum, 2025)

Technological investments have not always resulted in higher labour productivity, a phenomenon known as the productivity paradox (Brynjolfsson, 1993). This paradox stems from a lack of organisational, cultural, and skills-related integration during the initial adoption of these new technologies (Brynjolfsson et al., 2020). The absence of the necessary skills for business development or technological transformation has been evident during transitions such as to new, sustainable, service-based business models (González Chávez et al., 2023) or smart maintenance practices (Bokrantz et al., 2020). In addition to skills, appropriate working conditions influence work efficiency. Ipsen et al. (2021) found in their study on the impacts of working from home during the Covid-19 pandemic that, among other benefits, working from home could enhance employees' work efficiency. Other advantages include improved work-life balance and greater work control (Ipsen et al., 2021). However, they also identified some disadvantages of working from home, such as limited access to tools and other constraints (Ipsen et al., 2021). These new conditions must be considered when planning work.

To meet production workforce demands and support workers, human-centric research has been undertaken. Stahre (1995) proposed a tool for decision support and technology use to enhance human-machine interaction. The changing roles of factory workers, particularly operators, have been described by Romero et al. (2020). In their Operator 4.0 concept, workers are smart and skilled, leveraging digital technologies such as cyber-physical systems, collaborative robotics, wearables, augmented reality, and AI. The core idea is that an Operator 4.0 is not replaced by machines but augmented to become more flexible, empowered, and efficient. Human-centricity has become a vital factor in workplace design to optimise human mental workload (Cao et al., 2025). AI, together with collaborative robots, can augment humans, for instance, in improving recycling processes (Aschenbrenner et al., 2023).

Additionally, workplace training is optimised through technologies such as virtual reality (Söderlund et al., 2024). Research was also conducted to improve work instructions by leveraging augmented reality solutions to guide workers in their tasks (Syberfeldt et al., 2016). As practical applications demonstrate, it is not straightforward to determine when and how to implement these technologies. The Augmented Workforce Canvas (Moencks et al., 2022) is a tool that helps decision-makers involve operators in improving work situations on the shop floor.

Furthermore, Romero and Stahre (2021) propose the Operator 5.0 concept to meet new demands for resilience and sustainability, while placing even stronger emphasis on human-centricity. Here, the operator is an empowered, inclusive, purpose-driven worker who actively contributes to intelligent, ethical, and sustainable production systems, not just assisted by technology, but co-creating value with it. In terms of skills,

the Operator 5.0 has an even stronger focus on soft skills like ethical thinking, sustainability mindset, and resilience (Romero and Stahre, 2021, Pinzone et al., 2024). This shift from Operator 4.0 to Operator 5.0 highlights strongly the concerns connected to worker displacement, mental health, and inequality since Industry 5.0 and Operator 5.0 advocate a more balanced relationship between people and technology, always having the environment in mind: “The Operator 5.0 is a professional and purposeful worker enabled, assisted, and empowered by human-centric technologies, engaged in sustainable innovation, and contributing to societal well-being.” (Romero and Stahre, 2021)

## 2.2 SKILL GAPS

Technological change creates a skill gap because specific tasks evolve and require new human skills (Roblek et al., 2016). Skill gaps, labour shortages, and skill mismatches are terms used to describe challenges companies face in finding or developing the right talent (McGuinness et al., 2018, McGuinness et al., 2017). More specifically, skill gaps arise when employees do not meet their employers' skill needs (Rikala et al., 2024). This happens when businesses aim to implement new technologies, become more sustainable, or transform their strategies but struggle to recruit the right employees to support this transformation (Stavropoulos et al., 2023). Skill gaps are recognised as the main obstacle to successful business transformation (World Economic Forum, 2025). In the manufacturing sector, in particular, having skilled workers is a crucial competitive advantage (Chryssolouris et al., 2013). Therefore, companies and policymakers are seeking solutions to bridge skill gaps. As demographic shifts make recruiting young and skilled talent more difficult, upskilling and reskilling are highlighted as key solutions to address these gaps (World Economic Forum, 2023). According to the World Economic Forum's Future of Jobs report (World Economic Forum, 2025), 59% of the global workforce will need reskilling or upskilling to meet industry demand; however, 11% of them are unlikely to receive such training (World Economic Forum, 2025).

The skills currently most in demand are both technological and transferable. To support managers in hiring and training, Pinzone et al. (2023) defined Industry 4.0 skills through focus groups and interviews. Trevisan et al. (2024) defined the skills needed for the twin green and digital transition. The newest Future of Jobs report (World Economic Forum, 2025) highlights ten skills that are most important for people to learn or develop: analytical thinking and innovation; active learning and learning strategies; complex problem-solving; critical thinking and analysis; creativity, originality and initiative; leadership and social influence; technology use, monitoring, and control; technology design and programming; resilience, stress tolerance, and flexibility; and reasoning, problem-solving, and ideation. In their 2019 report, the World Manufacturing Forum (2019) highlights digital literacy, AI and data analytics, creative problem solving, entrepreneurial mindset, working physically and psychologically safely, and intercultural and -disciplinary, inclusive, and diversity-oriented mindset, privacy and data mindfulness, handling increasing complexity, communication skills, and an open-mindedness towards constant change as the top skills for the future of manufacturing. In the era of Industry 5.0, skills have been organised into four clusters: green industrial transformation skills, digital and resilient manufacturing skills, digital human workstyle skills, and technological systems skills (Pinzone et al., 2024).

To bridge one's skill gap, it is essential to identify the skills that are missing. Efforts to measure skill gaps have mainly involved developing a skill framework for a specific domain or job role through interviews, focus group workshops, or analyses of available data on job platforms such as LinkedIn (Rikala et al., 2024, Do et al., 2023, Zheng and Shi, 2022). In this approach, the skills framework is developed and then used to ask learners to self-assess their skills. In some cases, managers were also consulted to assess their employees' skills. The managers' assessment was found to be less biased than the employees' self-assessments (McGuinness and Ortiz, 2016). Other research on identifying suitable learning recommendations has focused on course recommender systems (Guruge et al., 2021). Recommender systems are commonly used, for example, in streaming services to recommend content that users are most likely to enjoy (Guruge et al., 2021). One example of these systems is collaborative filtering recommender systems, which leverage users' previous choices along with data from similar users to predict what a user might like (Linden et al., 2003). Methods used in more recent publications include data mining, such as pattern discovery and rule definition (Portugal et al., 2018). The advantage of these systems is that they learn over time. With the rise of AI, approaches connected to machine learning, such as using decision trees or neural networks, are emerging (Braun et al., 2022b, Portugal et al., 2018). Another approach uses questions to step by step gather information from the user to make personalised recommendations (Kumar and Ganapathy, 2020). Pontes et al. (2021) propose a concept to match individuals with upskilling challenges to suitable courses by analysing their skill gap and identifying appropriate training. Their presented model is illustrated by applying it to two different trends, but there is no empirical data collection to validate the tool. In a novel approach to match people to future-ready skills, Fareri et al. (2023) propose the "worker profiler" tool, which identifies people's digital and green skill gap and recommends suitable learning for them. Their solution is based on patent analysis to understand how specific job roles connected to sustainability and digitalisation are changing. Their solution is also illustrated with some examples, but no quantitative validation of the tool has been made.

## **2.3 STRATEGIES TO BRIDGE SKILL GAPS**

As skill gaps have become a pressing issue for industries, governments worldwide have launched initiatives to support individuals and employers in bridging them. This subsection presents some policy initiatives. Moreover, companies play an essential role in supporting their employees' workplace learning. Research on learning management in companies is presented here. The next subsection discusses the individual's perspective on learning and how to increase learning motivation. Lastly, education providers play a key role in bridging skill gaps, and this subsection provides background on their role and research on course recommender systems.

### **Policy initiatives**

In his report to the European Commission, former Italian Prime Minister and economist Mario Draghi stated that Europe must focus on innovation, reduce dependencies, and decarbonise the economy to remain competitive (Draghi, 2024). This report laid the foundation for the European Competitiveness Compass, presented by the European Commission in January 2025, which outlines strategic directions for these areas

(European Commission, 2025a). These three focus areas are complemented by five horizontal enablers, one of which is to promote skills and quality jobs. As part of this enabler, the European Commission launched the Union of Skills to enhance lifelong learning, quality education, and training to address labour and skills gaps that are holding back Europe (European Commission, 2025b).

At the country level, European governments launch initiatives to promote skills. Sweden's digital transformation strategy shows that digital expertise is critical to Sweden's competitiveness (Foka et al., 2025). Sweden's Ministry of Education launched a STEM strategy in February 2025 that covers STEM learning from preschool to adult education (Utbildningsdepartementet, 2025). The aim is to boost participation in STEM by introducing flexible education and coordinating efforts across industry, regions, and education. According to a report by the Swedish Ministry of Climate and Enterprise on Sweden's industrial strategy (Klimat- och näringslivsdepartementet, 2025), the need for a skilled workforce to ensure competitiveness and, therefore, close collaboration between education and industry, was essential. In their scenario analysis, Foka et al. (2025) suggest future scenarios for Sweden's digital skills and lifelong learning strategy. Among these scenarios, Foka et al. (2025) highlight the importance of talent mobility between continents, industry-driven upskilling initiatives, increased individual responsibility, and a new agility in higher education.

In Singapore, the government launched the SkillsFuture initiative to support Singaporean citizens in developing their skills and advancing their careers (Government of Singapore, 2023, Tan, 2017). Every Singaporean gets a skill credit each year, which they can use to learn new skills on the SkillsFuture learning platform. As of 2024, 37% of Singaporeans have utilised their skill credit since its launch in 2016 (Government of Singapore, 2025). The initiative also supports work on getting a common understanding of industry's skill needs, which is important for both individuals and education providers. In 2023, 64% of learners in the Singapore SkillsFuture programme reported advancing their careers thanks to the courses they took (Government of Singapore, 2025).

Another example of a skills initiative is the Canadian Upskill Canada programme, through which the Canadian government invests \$250 million in its people's upskilling and reskilling (Government of Canada, 2025). This initiative focuses on creating a successful skills ecosystem for workers in high-growth sectors to enhance Canadian competitiveness. Palette Skills was selected by the government to deliver a solution for this employer-driven upskilling programme and is expected to support 15000 Canadian workers in their upskilling or reskilling (Palette Skills, 2025).

## **Learning management**

Companies have started to realise that effective learning management is critical for closing their skill gaps in increasingly complex industrial environments. The industrial transformation reshapes jobs, and, alongside demographic trends, companies face increasing pressure to invest in upskilling and reskilling (World Economic Forum, 2023). However, learning while already employed has long been a topic of interest. Organisational learning highlights an organisation's continuous ability to adapt and

learn by reflecting the current transformations (Argyris and Schön, 1978). Within this framework, knowledge management systems serve as enablers of strategic learning by capturing, storing, and disseminating knowledge (Nonaka and Takeuchi, 1995) by leveraging communication and information technology (Sørensen and Lundh-Snis, 2001). Although work-integrated learning plays an essential role in closing skill gaps, some skills, such as problem-solving, are more effectively developed through informal learning (Hämäläinen et al., 2019). There is a need to understand the different learning circumstances of different employees. Shop-floor operators often lack access to computers and can't leave their workspaces for training, which makes it challenging to participate in traditional upskilling programmes (Roth et al., 2022). Roth et al. (2022) uses technology-mediated learning in her studies to explore how technologies can support a human-centric way of learning by implementing micro-learning, Augmented Reality, or Virtual Reality training. The result of her research is a framework to help managers integrate, implement, and evaluate technology-mediated learning (Roth et al., 2022). Industrial managers can use this framework to guide technology integration for learning by considering the dimensions (Roth et al., 2022): 1) Technology – what technologies are available that could enhance learning? 2) Organisation – which organisational dimensions should be considered? Who are the involved stakeholders, and what strategy is in place? 3) Environment – what external shocks, paradigm shifts, or labour market changes affect the learning environment? and 4) Learning – which skills should be acquired, and how might the design of learning be structured?

Roth et al. (2022) describes the connection between these dimensions as resembling an onion, with learning at the center focusing on individual needs, extending to technological and organisational dimensions at the firm level, and ultimately reaching the environment, which considers societal-level developments.

Various methods exist for defining learning metrics within organisations. One way to describe learning outcomes is Bloom's taxonomy (Adams, 2015), which outlines cognitive skill levels arranged in increasing complexity, from knowledge to comprehension, application, analysis, synthesis, and evaluation. Many firms employ the Kirkpatrick Four Levels of Evaluation to assess learning programmes, which distinguishes between reaction, learning, behaviour, and results (Kirkpatrick and Kirkpatrick, 2006).

One major question connected to upskilling is how to motivate employees to learn continuously. Grant and Parker (2009) found that autonomy and personal growth are positively correlated with motivation and performance. To motivate employees in online learning, feedback, relevance, flexibility, and adaptation to their own needs proved essential (Braun et al., 2022a). Furthermore, the Vice President of learning at Udemy describes the company's learning strategy (Osborne, 2020) and how it demonstrates learning's return on investment by linking skill development to business results, employee retention, and innovation, which are essential to securing management commitment and employee motivation. In her book, she also advocates making learning accessible to all employees, building a culture of feedback, and celebrating mistakes, as these are critical for maintaining a growth mindset. Dweck (2006) presented the theory of growth mindset, which provides a foundational psychological framework: individuals who believe abilities can be developed are more likely to embrace challenges and persist

in learning. Promoting this mindset in organisations leads to higher learning engagement (Yeager and Dweck, 2012). Further, psychological safety is a condition needed for learning, defined by Edmondson (1999) as an environment where individuals feel confident that they can take interpersonal risks, such as asking questions or admitting mistakes, without being scared of negative consequences. Psychological safety and learning are positively correlated (Edmondson and Lei, 2014). In recent years, especially amid working from home, the question of leadership at a distance has become increasingly important. Poulsen and Ipsen (2017) find that managers who can't be in the same place as their employees must put special emphasis on building trust to ensure employee well-being and motivation.

In organisations, questions related to upskilling are often addressed by Human Resources (HR) or Learning and Development (L&D) departments, which are also experiencing significant transformations in their approaches (Deloitte, 2016). HR management plays a vital role in identifying employees' skill gaps and selecting appropriate training to prevent ineffective training investments (McGuinness and Ortiz, 2016). Daniela Proust, global vice president and head of global people enablement and growth at Siemens, speaks in an interview with MIT Technology Review Insights (2022) about their company-wide solution to tailor learning to individual needs, by leveraging algorithms and matching to find the most suitable learning opportunities. It is further highlighted that it's not enough to offer learning to employees; the organisation must create support systems and motivate employees to learn (Boeren, 2023). Prosocial motivation is when motivation is based on the desire to benefit others. According to Grant (2008), when combining prosocial motivation with intrinsic motivation, the employee would put more effort in learning, given that they knew the new skills would benefit the organisation, their customer, or colleagues.

## **Education providers**

The upskilling challenge is difficult for industry alone to master, which is why collaboration with education providers, such as universities and vocational education institutions, is essential. In a recent publication, Vuoriainen et al. (2025) presents six key practices to foster this collaboration, namely “clarity, communication, commonality, commitment, continuity, and confidence”. These key principles are expected to be success factors for industry-academia collaboration.

Education providers are key actors in addressing skill gaps. Fast technological advancements and demographic change require new ways of thinking to adapt curricula and courses to industry's needs, as well as to deliver learning in modular, flexible, and demand-driven formats (UNESCO, 2021). To meet the industry's need for skilled talent, universities collaborate with industry partners to develop a shared understanding of skill gaps (Braun et al., 2024b).

Some universities offer massive open online courses (MOOCs) to meet demand for flexible online education, but completion rates among learners remain low (Onah et al., 2014). The Swedish Upskilling programme Ingenjör4.0 brings together 13 Swedish universities that collaboratively offer learning modules to engineers who need upskilling in Industry 4.0 and sustainability-related topics, and throughput numbers are higher

(Ingenjör4.0, 2023, Braun et al., 2023). Learning factories, often based in university facilities but developed in collaboration with industry partners, provide a real-world industrial environment for learning and research (Abele et al., 2015).

For education providers, such as universities, it becomes increasingly important to adapt quickly to new requirements based on the skill gaps among their students. Studies indicate a challenge and research gap in understanding an individual's skill needs, specifically in measuring the skill gap (Braun, 2023, Braun et al., 2022b, Braun et al., 2022a, Fareri et al., 2023, Rikala et al., 2024, Guruge et al., 2021). For this reason, solutions to measure skill gaps and match skills to suitable training have been studied (Rikala et al., 2024) and commercial solutions for skill matching have been launched.

Additionally, universities and their teachers face challenges in transitioning from delivering education programmes to students to delivering short online courses to industrial practitioners (Vuoriainen et al., 2025). Learning is conducted differently when the learner is an adult working in industry, with a very individual experience and background, and a tight work schedule. There is a risk of reduced motivation to learn, which could be mitigated, for instance, by providing feedback and individualising examples and content to their needs (Braun et al., 2022a). Feedback is an efficient tool in learning and has a massive impact on the achievement of learning goals, but it is essential to give feedback in the right way, by asking the learner what their as-is status is, where they want to go, and what they will do to get there (Hattie and Timperley, 2007). According to Bengmark (2023), one of the key competencies of a teacher is to assess a student's skill and find out their skill gap. In his model, Bengmark (2023) presents three pillars as the key competency areas of a teacher, namely the competency about the subject that is taught, the competency to cultivate learning, and the competency to lead. Assessing skill gaps and providing feedback to support learning progress are included in this model.



# 3

## METHODOLOGICAL APPROACH

*Work saves [...] from three great evils: boredom, vice, and need. - Voltaire*

In this chapter, the research approach is explained and linked to the author's worldview. The methods used in this research are outlined.

### **3.1 AUTHOR'S BACKGROUND AND WORLDVIEW**

The industry is undergoing significant changes, including digitalisation, new sustainability standards, pandemics, and shortages of skills and labour. These changes affect companies' competitiveness and people's well-being. Coming from an engineering background, it is vital for me to conduct research that is useful and impactful for industry personnel. Therefore, contributing to finding solutions is important to me. In my research, I have always focused on the human-centric aspect of industry—people's backgrounds, experiences, and needs—and how these influence their behaviour, as well as ways to support them.

While humans perceive situations differently, I believe that there are mechanisms that define phenomena, in this case, skill gaps. Although people experience skill gaps in their own context and with their own experiences, the concept of a skill gap and its possible solutions have common characteristics. This reflects a critical realist ontology (Easterby-Smith et al., 2018), which assumes that an objective reality exists, e.g., that skill gaps are an organisational challenge. Still, our understanding of it is individualised by our experiences (Easterby-Smith et al., 2018).

This work adopts a pragmatic epistemological approach, grounded in the belief that knowledge is best evaluated by tackling real-world issues. Pragmatism emphasises the practical outcomes of ideas and prioritises actionable results over abstract theories (Easterby-Smith et al., 2018). This aligns with the problem- and solution-focused approach of this work, which aims to help companies close skill gaps through practical methods and proven solutions. Rather than formulating universal theories, this research seeks to guide decision-making in complex and evolving environments by drawing on practical experience.

This pragmatic approach requires a methodology that uses empirical data to solve problems and design a solution to the challenge. A methodology that generates knowledge that works in real-world situations is Design Research methodology (DRM) (Blessing and Chakrabarti, 2009). The research employed DRM to understand the skill gap problem, develop a deep understanding of stakeholder needs, propose a solution, and evaluate its outcome. The aim of this methodology is not only to understand the problem and create scientific value but also to provide practitioners with relevant tools and recommendations. DRM enables us to answer the research questions using both qualitative and quantitative methods, depending on what is needed, since the relevance and usefulness for practitioners are at the centre.

### **3.2 RESEARCH DESIGN**

The research questions guided the design of the methodology used for this thesis, namely RQ<sub>1</sub>) *What is a skill gap in the industrial context?* RQ<sub>2</sub>) *How can skill gaps be measured?* and RQ<sub>3</sub>) *How can skill gaps be bridged?*

#### **3.2.1 Design Research Methodology (DRM)**

DRM is a problem- and solution-oriented approach to conducting research (Blessing and Chakrabarti, 2009). When employing this methodology, the first step is to

understand the problem through a literature review and to establish the research goals. The next step is to gather empirical data to examine and describe the problem in depth. In the third phase of DRM, an assumption is made regarding how the problem could be solved, and a support tool or alternative solution is implemented. Finally, this implementation is assessed by collecting empirical data on the users. These steps can be repeated iteratively to design a solution that addresses the problem. Naturally, the evaluation of the solution could lead to the acknowledgement of missing data collection from certain stakeholders or to the discovery of new problems, which is why the arrows signal that it's possible to loop back within this process.

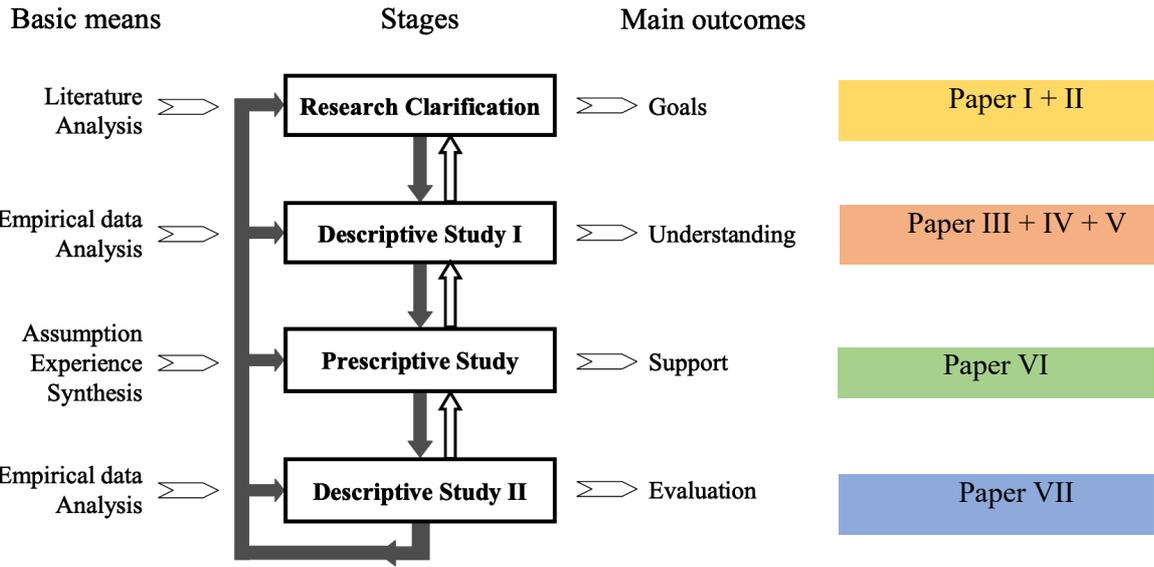


Figure 1 - DRM applied to this work (adopted from Blessing and Chakrabarti (2009))

The studies presented in Papers I-VII have been carried out across four different projects and collaborations. Paper I and Paper II are based on an extensive literature review conducted with a team at the University of Jyväskylä through a partnership focused on shared interests in skill gaps. Paper III is based on the Ingenjör4.0 project, a national Swedish upskilling initiative led by Halmstad University and involving 13 Swedish universities. Paper IV is also a collaborative effort in which the Ingenjör4.0 team partnered with the University of Jyväskylä to conduct an extensive interview study with participants worldwide. Paper V originates from a project commissioned directly by the European Commission, Directorate-General for Research and Innovation, which involved an Industry 5.0 Learning and Assessment tool. Paper VI results from implementing a skill-matching solution within the Ingenjör4.0 project. Finally, Paper VII stems from a collaboration with Fraunhofer IPK in Berlin, in which a team implemented the same skill-matching solution as in Ingenjör4.0, as discussed in Paper VI. Therefore, Paper VII synthesises the results from these two contexts to offer further recommendations.

Table 1 - Research activities and their alignment with the appended papers.

	Paper I	Paper II	Paper III	Paper IV	Paper V	Paper VI	Paper VII
RQ1 - Define	x						
RQ2 - Measure	x			x		x	x
RQ3 - Bridge		x	x	x	x	x	x
Stage in DRM	Research Clarification		Descriptive Study I			Prescriptive study	Descriptive study II
Research activities conducted	Literature review to define skill gap + understanding ways of measuring skill gaps	Literature review about stakeholders involved in skill gaps	Qualitative survey to identify dimensions of challenges and success factors from the learners' perception	Interview study to understand how companies worldwide bridge their skill gaps + the challenges	Survey interview study to understand workforce readiness towards Industry 5.0	Present the implementation of skill management tool + describe challenges	Implement a skill management solution and evaluate the results
Outcome	Defined "skill gap". Overview of methods to measure skill gaps.	Defined stakeholders involved in skill gaps. Defined actions for stakeholders.	Identified learners' challenges and success factors. Main challenge is individual needs.	Defined five key areas covering companies' practices and challenges when managing skill gaps, synthesized in the "skill bridge".	Identified three company clusters based on their Industry 5.0 workforce readiness regarding skills, upskilling, and workforce resilience.	Implemented a skill management tool and described challenges e.g. related to taxonomy, manual work.	Suggested recommendations for a skill management platform.

The following subsections give a detailed description of the methodologies used in the studies, arranged according to the four DRM steps.

### Research clarification

The first step in this research was to gain a general understanding of the problem. By clarifying the concepts, mapping previous research in the field, and identifying evidence, a foundation was created to address the problem. The problem, as noted earlier, was the lack of skills among workers in industry, which hindered technological and sustainable

transformation. This was often referred to as a 'skill gap', but the term has been used in various ways. In this step, the research goals became clear: to understand the mechanisms that drive skill gaps and to develop strategies, methods, and tools to bridge them. This led to RQ1: "What is a skill gap in the industrial context?" Additionally, there was no clear understanding of how to measure skill gaps. It seemed necessary to develop methodologies that help identify the skills an individual is missing, thereby enabling them to bridge those gaps.

Ultimately, Paper I originated from a literature review of 40 articles on the definition of the term 'skill gap,' along with related terms such as 'skill shortage' and 'skill mismatch.' This literature review also mapped previous research on methods for measuring skill gaps. This study identified a research gap in understanding and measuring skill gaps. Paper II emerged from the same literature review but focused on which stakeholders are involved in addressing the skill gap and what actions they take. The identified stakeholders were employers, employees, education providers, and policymakers. With these findings and the demographic shift in mind, it became evident that the way to bridge skill gaps is to upskill the existing employees.

After conducting these studies, the need for empirical evidence and an understanding of the practical mechanisms associated with these concepts became evident.

### **Descriptive Study I**

In this research step, an empirical analysis was conducted to deepen understanding of the stakeholders involved in this issue, the challenges they face, and the potential success factors and strategies to overcome those hurdles. Given the complexity of this research topic, there was a strong conviction that empirical studies involving multiple stakeholders were necessary.

First, a survey of 137 engineers in an upskilling context was conducted to understand their challenges in on-the-job learning and to identify potential success factors in their learning. The main conclusion was that learners have highly individual needs and that training must be adapted accordingly. Thus, a learning path should be tailored to individual needs, flexible in its timing, and adaptable to learners' work contexts. However, a research gap was identified. There was a lack of studies using tools that help learners understand which skills to learn and which training to enrol in. This is presented in Paper III.

Alongside this employee study, an interview study involving 23 company leaders from around the globe was conducted to gain insights into how organisations manage their skill gaps. This study yielded a framework, the skill bridge, which illustrates how companies address their skill gaps. This was achieved through thematic analysis of the 23 interviews, which detailed managers' skill management practices and highlighted the challenges they faced in addressing skill gaps, as presented in Paper IV.

Additionally, a survey-based interview study was conducted with 160 managers and individuals in Europe regarding their workforce's Industry 5.0 readiness. The data were analysed and clustered based on the participating companies' responses regarding their skill levels, learning initiatives, and workforce resilience. The cluster analysis resulted in

three distinct clusters of companies with similar patterns. These characteristics were analysed to inform policymakers and recommend managerial practices. The results from the study are presented in Paper V.

### Prescriptive Study

Evidence from the literature and empirical studies indicates that skill gaps are multifaceted and pose various challenges for stakeholders. Given this skill gap, together with the demographic shift, upskilling was the most suitable solution; therefore, a tool to support it was required. The primary challenge identified was achieving a shared understanding of an individual's skill gap. This is particularly significant for employees, who need to know what to learn to remain relevant, and for employers, who are accountable for the success of their teams and staff. In recent years, advances in AI solutions for learning have led to the development and commercialisation of skill-management platforms. These platforms were investigated, and one was selected for implementation in the Ingenjör4.0 project to examine employees' and employers' perceptions of such a solution. This solution could address both RQ<sub>2</sub> and RQ<sub>3</sub>, i.e., measure skill gaps and suggest ways to bridge them. The implementation of this AI-based skill-management platform in the Ingenjör4.0 project was discussed in Paper VI. In this paper, the concept and challenges associated with implementing the solution are outlined.

### Descriptive Study II

After implementing the skill-management platform, it was essential to understand how employees and employers perceive the tool. The platform was tested with employees from four large companies in Sweden and two SMEs in Germany. Evaluation in these two contexts was conducted through surveys and focus group workshops, which identified several key criteria for developing a skill-management platform. These empirical data were analysed using thematic analysis, yielding recommendations for developing a skill-management platform. These are described in Paper VII.

### 3.2.2 Reflection on Research Design

This thesis adopts a critical realist ontology, assuming that skill gaps are real organisational challenges but are perceived differently by individuals and organisations. This assumption enables generalisation about skill gaps while accounting for contextual differences. Epistemologically, the thesis adopts a pragmatic approach, applying knowledge to real-world challenges. The challenge is shaped by a rapidly changing world, which makes it necessary to understand skill gaps in a broader context without getting lost in detail. This aligns with the vision of this work: to produce insights and solutions for industrial practitioners while also contributing new knowledge to theory. To operationalise this idea, the work follows the structured approach of DRM, which provides clear guidelines for understanding a problem and suggesting a solution while involving stakeholders in the process. DRM also supports iteration across stages and the application of different methods while maintaining a clear structure. Overall, this thesis employs a mixed-methods approach due to the complex nature of the challenge. This approach helped ensure that the findings were theoretically grounded, supported by

empirical data, and relevant to the practical challenge.



# 4

## RESULTS

This chapter presents the main findings from the seven appended papers. The DRM approach guides data collection in this study by understanding the problem, defining research goals, gathering empirical data to gain deeper insight into the challenges faced by stakeholders, suggesting a solution, and evaluating it. The chapter is structured according to the four steps of DRM to illustrate how knowledge was created step by step.

## 4.1 UNDERSTANDING THE SKILL GAP PROBLEM

The initial phase of the research focused on understanding the concept of skill gaps and identifying the stakeholders involved by analysing prior literature.

### Paper I

The literature review in Paper I showed that skill gaps are a complex issue. The main causes of skill gaps are megatrends such as digitalisation, globalisation, and demographic shifts. It was observed that when business needs change, the operating environment shifts, along with tasks and the skills required. This affects employees, employers, and education providers. Employees must adapt to the changing demands with their existing abilities or risk becoming obsolete in their skill sets. Employers need to identify strategies to ensure they have suitably skilled workers, or risk losing competitiveness. Education providers must modify their training programmes to meet the industry's evolving needs or risk creating an education gap. Skill gaps highlight the difficulty of matching the right skills with the right people at the right time. Closing the skill gap improves organisational performance, bridges business gaps, and supports digital and sustainable transformation. The skill gap is the difference between the demand for skills and the supply of skills. (Rikala et al., 2024)

Furthermore, the review of existing literature identified methods for measuring skill gaps, such as collecting data from students, employees, employers, and education providers through surveys, interviews, or focus group workshops. Additionally, other data collection approaches for assessing skill gaps include analysing the literature, examining databases of job postings and profiles (e.g., the European Skills, Competences, Qualifications, and Occupations ESCO or the US Department of Labor platform O\*NET), and exploring professional social networks like LinkedIn. A method used in several publications was to create a skill framework including the skills within the concerned field or job role and use this framework to conduct self-assessment exercises with employees and their managers, and through that find out their skill gap (Do et al., 2023, Zheng and Shi, 2022).

### Paper II

Paper II examines how to further bridge skill gaps by identifying the involved stakeholders and proposing actions for them. According to Paper II, the key stakeholders responsible for tackling skill gaps are employers, education providers, policymakers, and researchers. The literature review identified crucial actions for these groups, such as forming partnerships and developing a shared understanding of the skill gaps and the skills needed. As illustrated in Figure 2, a strong core is essential, where employers and education providers collaborate and seek support from policymakers and the research community. This core is vital for enabling individuals, including employees, students, and job seekers, to engage in lifelong learning and adapt to changing requirements. (Braun et al., 2024b)

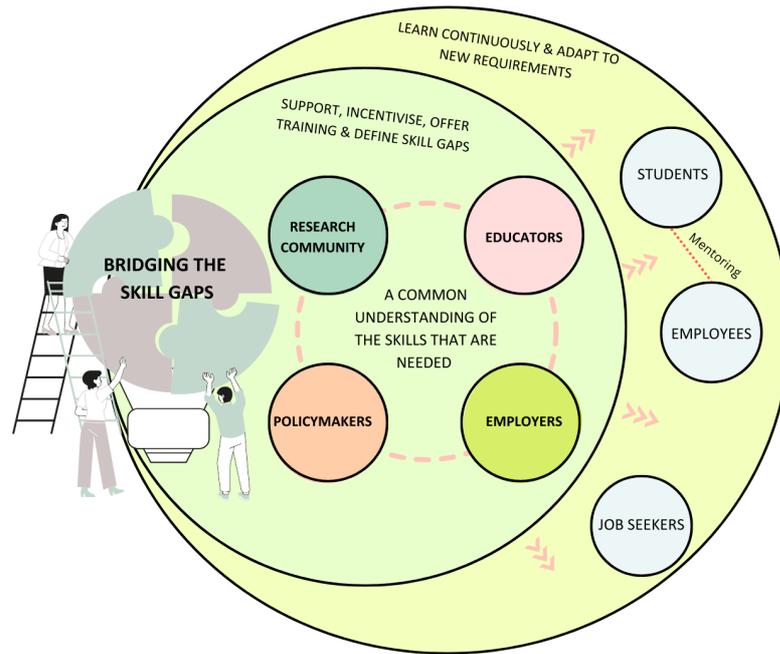


Figure 2 - Stakeholders in bridging skill gaps (Braun et al., 2024b)

From these two papers, the first step in this research yielded an understanding of skill gaps, the stakeholders involved, and an initial indication of the challenges they may face.

## 4.2 CURRENT PRACTICES

To develop an understanding of two identified stakeholders, namely employees and employers, three studies were conducted. The first, presented in Paper III, offers insights into the employee's perspective. This study examined the needs of individuals taking part in Ingenjör4.0 upskilling by analysing survey responses from 137 participants in the Ingenjör4.0 project. Next, a study was conducted to incorporate the perspectives of employers worldwide, involving 23 leaders, and the findings are presented in Paper IV. The final piece of the puzzle is understanding the industry's transformation in terms of skills and the workforce's readiness for the transition. This is addressed in Paper V. This study presents data from 160 European companies on their Industry 5.0 workforce readiness regarding skills, upskilling, and workforce resilience. These three papers aimed to understand the needs of different stakeholders to suggest better solutions that add value. The results of these three studies are summarised below.

### Paper III

The main message of Paper III is that upskilling programmes such as Ingenjör4.0 can help boost employees' skills. However, success factors can further motivate and enhance the effectiveness of upskilling. These include creating a relevant training or learning path that addresses individuals' needs. Additionally, the organisation and structure of the upskilling programme are important to participants, who emphasise the need for the freedom to learn at their convenience. Furthermore, adapting the work environment is seen as a crucial factor that should be personalised for each individual's workplace.

Participants also highlighted the importance of personalised support and teacher feedback. Lastly, they valued the opportunity to interact with other learners and share ideas. (Braun et al., 2023)

The main takeaways from this paper were that online upskilling programmes benefit from collaboration to deliver cutting-edge training, as in the Ingenjör4.0 project, and that the platform should offer personalised support tailored to learners' individual needs, as well as enabling teachers to develop training effectively. Employees requiring upskilling need efficient access to training that is tailored to their work context, neither too easy nor too difficult. (Braun et al., 2023)

## Paper IV

As identified previously in Paper II, employers are a key stakeholder in addressing skill gaps. However, a research gap remains, and the literature calls for empirical studies on the management of skill gaps. To fill this gap, the study presented in Paper IV involves 23 leaders from large companies worldwide who shared their approaches to supporting employees in acquiring new skills, including the initiatives they have implemented, how they determine which training is necessary, success stories of upskilling within their organisations, how they cultivate a lifelong learning culture, the challenges they face, and the long-term impact of their initiatives.

This study identified five key priority areas for managers or employers: Skill development initiatives, Knowledge empowerment, Impact and business results, Leadership and culture, and Learning technologies and innovation (Braun et al., 2025b).

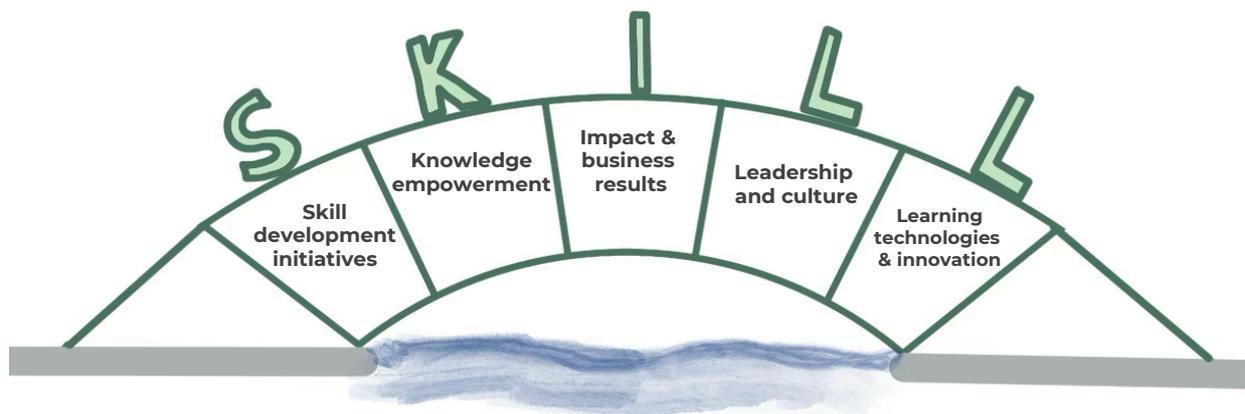


Figure 3 - The Skill Bridge (Braun et al., 2025b)

Regarding **Skill Development Initiatives**, managers described their upskilling efforts, including partnerships with external education providers such as Coursera and LinkedIn Learning. Some also mentioned tailored training programmes that meet their company-

specific needs. A priority for some respondents was to ensure flexibility and free access to digital learning for all employees. However, challenges included limited budgets, language requirements, time constraints, and the difficulty of delivering in-depth or practical training, particularly for blue-collar workers without access to computers. The respondents also noted a gap between rapidly changing skill needs and the slow pace of course updates in formal education. (Braun et al., 2025b)

The next priority area identified was **Knowledge Empowerment**. Companies described empowerment structures, including using engaging platforms, mentorship programmes, learning competitions, and incentives such as time allocation, monetary rewards, and certifications. Respondents emphasised the importance of cultivating a self-motivating culture and of receiving support from colleagues and fellow learners. However, they reported challenges such as resistance to change, difficulty prioritising learning over daily tasks, stress from ongoing upskilling demands, and mismatches between training content and job relevance. Another issue mentioned was that some employees overestimated their abilities or lacked the capacity to acquire the required new skills, necessitating more individualised support. (Braun et al., 2025b)

The third priority area, **Impact and Business Results**, recognises the importance of aligning skill development with long-term business objectives. Many respondents have not established clear KPIs to measure the impact of learning initiatives, but emphasise that such alignment is important. In the respondents' organisations, strategic workforce planning and regular skill gap analyses are conducted, yet there is no clear understanding of the effectiveness of these measures. Interviewees highlighted challenges such as a lack of strategic competence management, unclear future skill requirements, and difficulties in balancing short-term demands with long-term development. Furthermore, talent scarcity remains a significant challenge, emphasising the need for a skill-based approach. (Braun et al., 2025b)

Next, **Leadership and Culture** was recognised as a priority area. Leaders play a crucial role in fostering a learning environment by being role models, setting strategic directions for learning, and supporting employee development through resources and assistance. Both bottom-up motivation and top-down guidance are highlighted as ways to encourage employee engagement. Some respondents mention the link between manager incentives and learning outcomes in their company. However, several challenges remain, including managers' reluctance to acknowledge their own skill gaps and resistance to cultural shifts toward continuous learning. Moreover, psychological safety is vital because ongoing change can overwhelm employees and impede their skill development. (Braun et al., 2025b)

Lastly, **Learning Technologies and Innovation** became a priority area. The study shows that companies are increasingly using technological tools to manage employees' skills, personalise learning, visualise progress, and forecast skill needs. Some employ solutions such as Learning Management Systems (LMS), AI chatbots, and scenario planning to strategically enhance their workforce's skills. However, challenges include inconsistent use by managers and employees, immature systems, transition difficulties, and inaccuracies in self-assessments of skills. In conclusion, technological tools alone do not deliver value; organisational integration, achieved through dialogue between

managers and employees, is essential. Table 2 provides an overview of these results, organised by the practices and challenges of each of the five themes.

Table 2 - Practices and challenges across the five themes (Braun et al., 2025b)

Theme	Practices - How companies manage skill gaps	Challenges - What hinders them
<b>Skill-development initiatives</b>	<ul style="list-style-type: none"> <li>• External partnerships (Coursera, LinkedIn Learning)</li> <li>• In-house academies</li> <li>• Targeted up-/reskilling for AI, cloud, ESG etc.</li> <li>• Free digital access for all employees</li> <li>• Continuous-improvement cycles</li> </ul>	<ul style="list-style-type: none"> <li>• Training budgets and cost of providing in multiple languages</li> <li>• Scheduling around shift work / production lines</li> <li>• Academic curricula lag behind industry needs</li> <li>• Scarcity of expert-level learning content</li> <li>• Hands-on skills hard to teach online</li> </ul>
<b>Knowledge empowerment</b>	<ul style="list-style-type: none"> <li>• User-friendly LMS with leader-boards or learning “competitions”</li> <li>• Mentorships, communities of practice, external networking</li> <li>• Culture of lifelong learning</li> <li>• Incentives for certificates (e.g. money)</li> <li>• Active managerial coaching &amp; support</li> </ul>	<ul style="list-style-type: none"> <li>• Resistance to change, low intrinsic motivation</li> <li>• Hard to prioritise learning time over day-to-day work</li> <li>• Constant waves of change create stress</li> <li>• Self-assessment bias / overconfidence</li> <li>• Limited PC access for shop-floor employees</li> </ul>
<b>Impact &amp; business results</b>	<ul style="list-style-type: none"> <li>• Strategic workforce planning tied to future tech roadmaps</li> <li>• Recurring skill-gap analyses with dashboards</li> <li>• KPIs linking training, retention, employee wellbeing</li> <li>• Certification frameworks for career progression</li> <li>• Limited tracking of ROI on learning investment</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of unified competence strategy</li> <li>• Difficulty defining KPIs that capture learning impact</li> <li>• Budget/time trade-offs with short-term delivery pressure</li> <li>• Rapidly shifting skill demand</li> <li>• Gap-analysis data not always turned into action</li> </ul>
<b>Leadership &amp; culture</b>	<ul style="list-style-type: none"> <li>• Leaders act as visionaries, coaches, role models – have a responsibility</li> <li>• Top-down vision combined with bottom-up initiative</li> <li>• Psychological safety: mental-health &amp; mindfulness support</li> <li>• Learning outcomes tied to managers’ bonuses</li> <li>• Ecosystem collaboration to stay ahead of trends</li> </ul>	<ul style="list-style-type: none"> <li>• Managers’ fixed mind-sets</li> <li>• Managers’ reluctance to admit personal skill gaps</li> <li>• Short-term thinking culture hinders strategic thinking</li> <li>• Low psychological safety hides true gaps</li> <li>• Change fatigue &amp; stress during continuous transformation</li> </ul>
<b>Leveraging technology &amp; innovation</b>	<ul style="list-style-type: none"> <li>• AI-based skill mapping</li> <li>• LMS add-ons for gap assessment &amp; visual dashboards</li> <li>• AI-based skills-matching linking people to learning or jobs</li> <li>• Chatbots answering learning queries</li> <li>• Annual personalised skill-tracking loops</li> </ul>	<ul style="list-style-type: none"> <li>• High uncertainty as tech requirements evolve</li> <li>• Low user adoption / inconsistent data input</li> <li>• Legacy-system complexity slows roll-outs</li> <li>• Self-rating bias in automated assessments</li> <li>• L&amp;D workload spikes during platform changes</li> </ul>

**Paper V**

In the current industrial shift towards Industry 5.0, companies are trying to adopt new technologies and practices. However, there is limited understanding of the workforce’s readiness for this change. With the aim of building an understanding of companies’ workforce readiness, the study in Paper V leverages an Industry 5.0 Learning and Assessment tool, developed at the European Commission. The study posits that European competitiveness ultimately depends on the skills available in the workforce. To know how competitiveness can be achieved, companies wonder how Industry 5.0 could be adopted. Using the Industry 5.0 Learning and Assessment tool could help them understand what Industry 5.0 entails and how to proceed. To adopt Industry 5.0 principles, the workforce requires specific skills, upskilling, and resilience (see Figure 4.

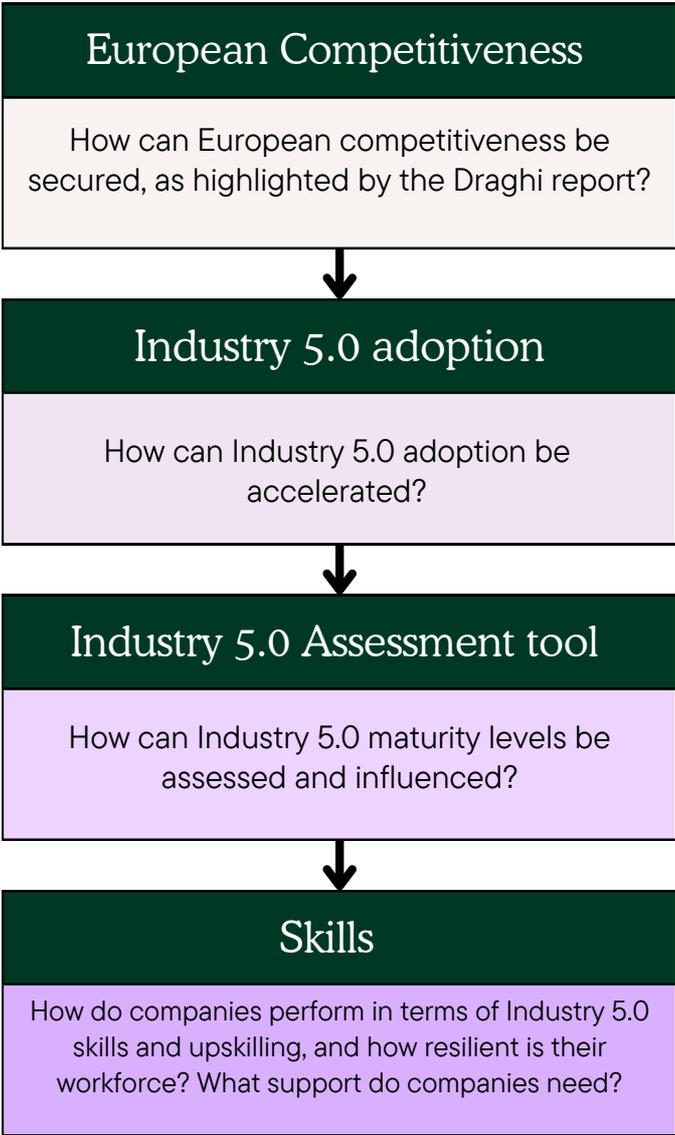


Figure 4 - From skills to European competitiveness (from Paper V)

The Industry 5.0 Learning and Assessment tool consists of 119 questions, of which 19 are specifically relevant to Industry 5.0 skills, upskilling initiatives, and workforce resilience.

These 19 questions were used in a cluster analysis of 160 respondents. The analysis yielded three clusters, namely Ad Hoc, Structured, and Adaptive. The three company clusters are characterised by different patterns, which is shown in Figure 5.

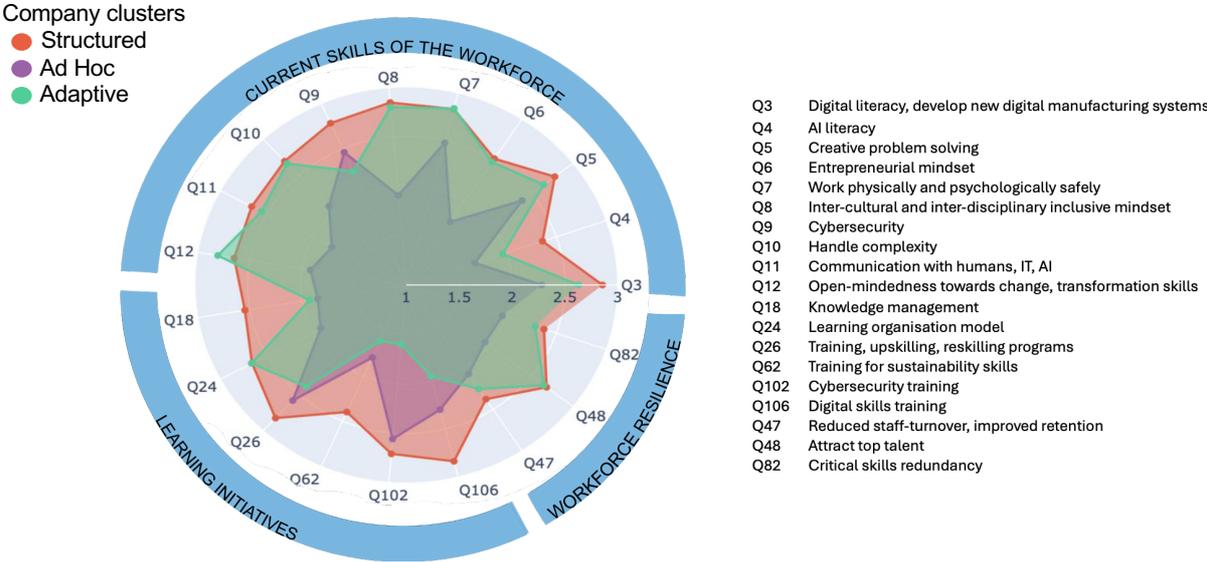


Figure 5 – Three company clusters characterised by skills, upskilling, and workforce resilience (Paper V)

**Ad hoc**, mainly mid-sized and large firms, tend to have lower skills in innovation and transformation skills, but excel in cybersecurity. This may be due to their hierarchical structures and slow decision-making processes. These features could limit workforce resilience. Ironically, to become more resilient, they would need to adopt agile innovation practices. Additionally, they could develop their skill management and prioritise psychological safety and a learning culture. Tailored policy support for these organisations can help them overcome cultural inertia and facilitate transformation.

**Structured** encompass a range of company sizes and are highly skilled in digital skills, entrepreneurial mindset, and transformation skills. However, compared to these high scores, they exhibit some weaknesses in AI and cybersecurity skills and in workforce resilience. Their strengths lie in technical areas, but they are less proficient in organisational strategies to manage uncertainty. To maintain momentum, Structured should develop a skills strategy and align its learning KPIs with learning initiatives. They could also offer tailored learning to their employees, e.g. through AI-based skill matching. Policymakers should support these efforts and assist Structured in building resilience while capitalising on their rapid transformation capabilities.

**Adaptive** are usually small firms and startups. They are open to constant change and possess strong transformation skills, but often lack formal training, AI and cybersecurity expertise, and effective knowledge management within the organisation. Nevertheless, their openness, inclusiveness, and capacity to manage complexity give them high potential for development, although the absence of structure makes them vulnerable.

These companies should prioritise team building and employee upskilling. These firms require targeted support from policymakers to develop flexible training programmes that meet their needs and to establish internal processes for knowledge sharing and workforce stability.

Overall, the outputs from Step 2 of the DRM approach provided a description of the current state of European industry with respect to skills, learning initiatives, and workforce resilience (Paper V). It also outlined the practices and challenges related to how global companies manage skill gaps (Paper IV). Finally, this step laid the foundation for the design requirements of a potential solution by understanding learners' needs in upskilling (Paper III).

### **4.3 PRESCRIBING A TOOL**

The experiences gained from Step 2 of the DRM approach led to assumptions that could be synthesised to propose a solution. Paper II highlights the need for alignment among stakeholders seeking to bridge skill gaps: employees, employers, education providers, and policymakers. Paper III emphasises the importance of personalised support for employees engaged in upskilling – learning must be tailored to their specific needs, as time is limited and each individual has unique development requirements. However, Paper IV shows that managers have different approaches to supporting their employees, and many lack clear strategies to identify skill and training needs, supported by technological solutions but constrained by their adaptation.

#### **Paper VI**

As described above, there was a strong need for a solution that helps employees, employers, and education providers collaborate to identify skill gaps and training for individuals. This solution would support the identification of individuals' skill gaps and match their upskilling needs to suitable training items. Lately, several startups have introduced skill-management platforms to the market. Rather than developing a new solution, a market analysis was conducted, and a single solution was selected. This solution was introduced into the Ingenjör4.0 project, which is described in Paper VI (Braun et al., 2024a).

This solution requires only two pieces of data from a user: their job role and the company they work for. Using this information, the system determines skill needs. This is illustrated in Figure 6.

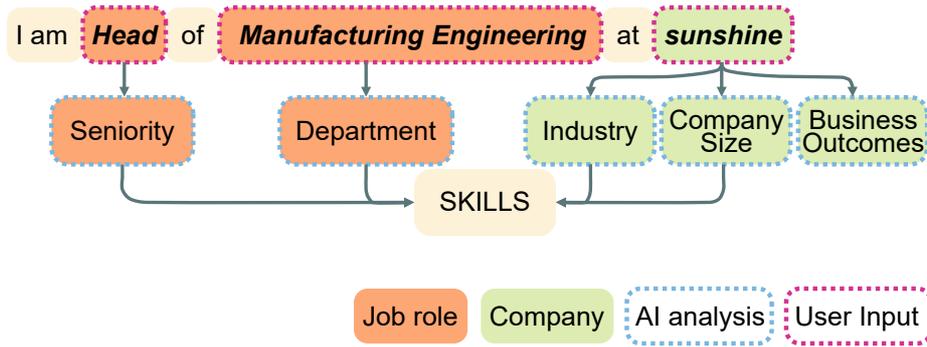


Figure 6 - Identifying skill needs (Braun et al., 2024a)

The skill-management platform was launched as part of the Ingenjör4.0 project. Ingenjör4.0 brought together 13 Swedish universities to create an online learning platform for engineers, on which all universities contribute modular courses. The skill-management platform uses open-source data, such as LinkedIn, ESCO, and O\*net, to collect information on job profiles, tasks, and skills. By knowing the user's job role and employer, the AI determines the skills the user needs to develop. The concept of the skill-management platform is shown in Figure 7. These skills appear on a dashboard, and in the next step, the user selects some of them to conduct a self-assessment. This highlights a skill gap, showing the user's skill demand. The demand is then matched to the available training options, which in this case include the Ingenjör4.0 training modules.

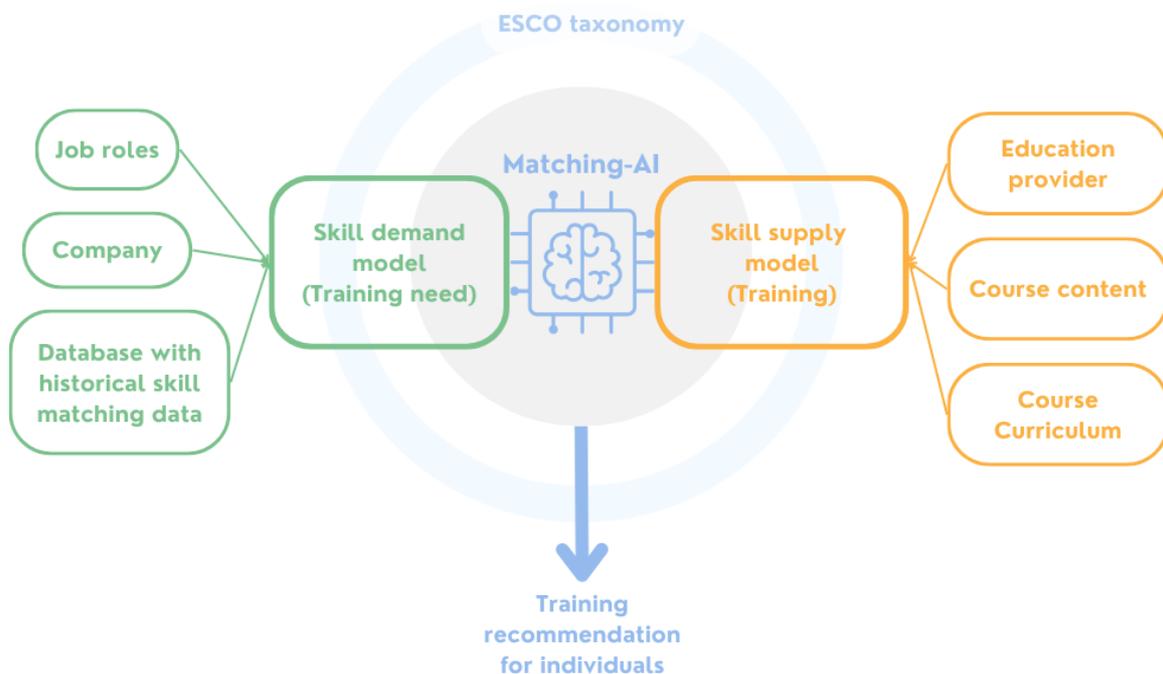


Figure 7 - Concept behind skill-management platform (Braun et al., 2024a)

Suitable modules are presented to the user on the platform, and registration can be completed immediately. This is illustrated in Figure 8.

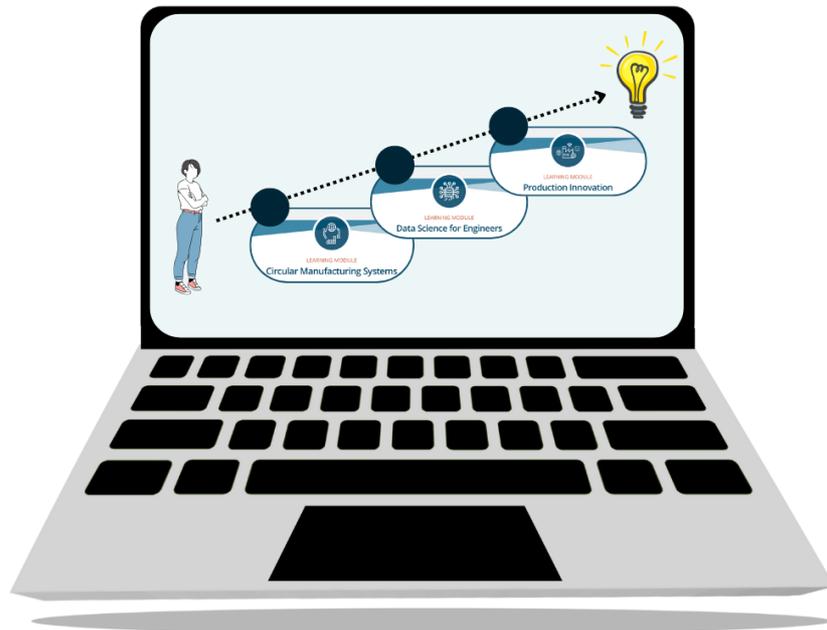


Figure 8 - Learning path presented in user dashboard (Braun et al., 2024a)

This solution could help users identify their skill gaps and direct them to appropriate training. For managers, the tool could support assessing and tracking employees' development and informing learning objectives. Education providers could gain insights into users' skill gaps, continuously refine their course offerings to meet current needs, and enhance the visibility of their programmes to prospective learners.

## 4.4 EVALUATION

In the final phase of this research, the skill-management platform presented in Paper VI was evaluated.

### Paper VII

Paper VII (Braun et al., 2025a) reports on the tool's evaluation in two settings: large Swedish companies and small- to medium-sized enterprises in Germany. The study considered two perspectives: users' perceptions and the platform's organisational integration.

As presented in Paper VII (Braun et al., 2025a), respondents who had used the platform reported varied experiences, both regarding the relevance of the recommendations to them and the platform's usability. Additionally, their trust in AI varied, with not everyone comfortable having their next step for skill development recommended by an AI. The analysis of responses also uncovered challenges related to differences in job, task, and skill taxonomies between companies, as well as organisational integration with existing HR and learning processes. Other challenges included the visibility of learning

progress for managers and user engagement in the skill assessment and development process. From a user perspective, the platform struggled to assess skills. Some users mentioned that the scales didn't feel intuitive. Additionally, there were mixed opinions about the training recommendations provided after assessing their skill gaps. Some found the recommendations relevant, while others struggled to see why they were relevant to their work or felt they were too generic. (Braun et al., 2025a)

Overall, encouraging users to spend time on the platform for assessments and learning recommendations was challenging. Participants noted that a face-to-face session with the platform provider could have helped allocate time to this task and boost motivation. Some users suggested improvements to increase engagement, such as adding gamification or visualising completed learning. (Braun et al., 2025a)

Triangulating these results with Paper II leads to the conclusion that policymakers' support is needed in the future development of upskilling platforms by creating the enabling conditions for successful launch and maintenance. To build further empirical evidence on the success factors of these platforms, policymakers should support pilot projects and research. Moreover, they should ensure inclusivity by ensuring that everyone is considered in the data used to match relevant skills. Lastly, policymakers should lead efforts to recognise alternative learning paths through online upskilling programmes and investigate whether credentials or certificates are suitable.

Based on the results, a figure was created to illustrate practices and recommendations for the three main stakeholders: platform designers/education providers, employees and employers, and policymakers, see Figure 9.

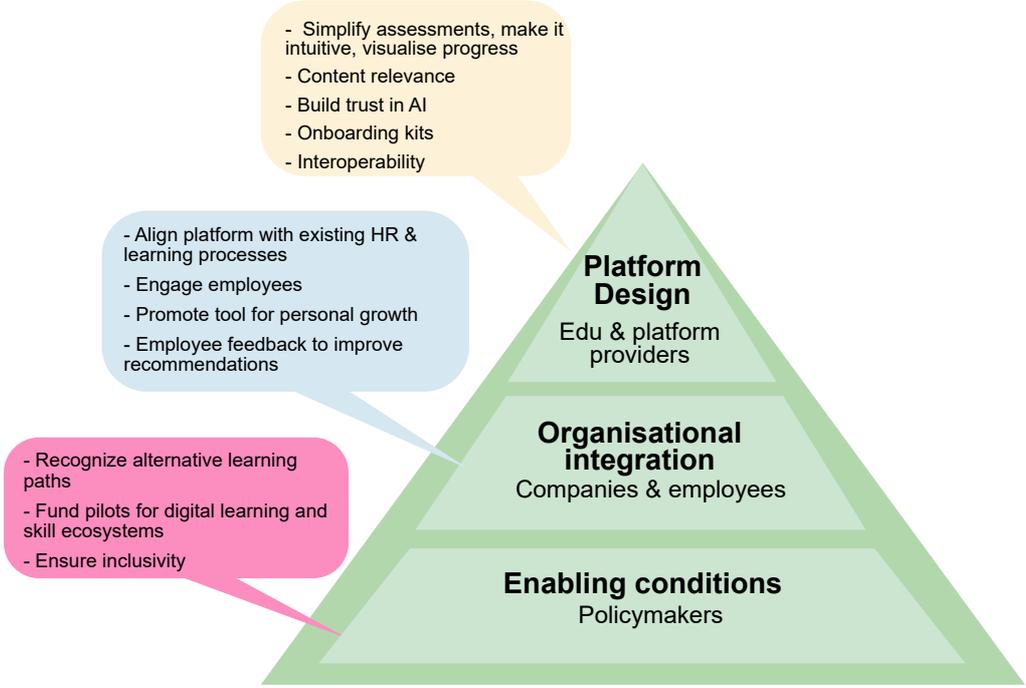


Figure 9 - Building a scalable skill management system (Braun et al., 2025a)

Beginning at the bottom of Figure 9, policymakers are working to establish the enabling conditions for a scalable skill-management platform. This could be achieved by 1) recognising alternative learning paths next to formal education, 2) funding initiatives and projects that implement and test these solutions on a large scale to gather empirical insights into users' perceptions, and 3) ensuring inclusiveness in the continuous learning ecosystem and leaving no one behind.

Companies and employees are the ones practising learning and integrating it hands-on into their organisations. For them, it's important to align the skill management platform with existing LMS. Employers have a responsibility to continuously motivate employees to learn and to promote such a tool for personal growth. Additionally, there should be feedback loops that enable employees and managers to provide feedback to the system and to continuously update and improve the tool.

On top of the pyramid are the education and platform providers who design the platform. Based on respondents' feedback, it is crucial to simplify self-assessments and to make them more intuitive and accurate. Also, the dashboard should include a visualisation of the employee's progress. Another challenge for platform providers is to improve content relevance for each individual, e.g., by incorporating feedback loops and enabling the system to learn over time which recommendations were successful. Additionally, building trust in AI could increase the platform's use. Participants appreciated face-to-face workshops to begin using the platform. This could be implemented in future setups. Lastly, there are significant challenges related to overlaps and integration with existing HR and learning platforms that companies already have. Platform providers, therefore, need to consider the interoperability of their platforms to ensure smooth implementation.

Table 3 - Summary of the main contributions from the appended papers.

DRM	Paper	Purpose	Main contribution to RQ1	Main contribution to RQ2	Main contribution to RQ3	KPIs
Research clarification	I	Define “skill gap” concept based on previous literature, synthesize methods to measure skill gaps.	Definition for “skill gap”: the gap between the skills employers require and the skills the employees possess.	Overview of skill measuring methods. Most highlighted method: create skill framework and survey to let employees do self-assessment regarding importance and performance of each skill.		40 papers reviewed
	II	Identify which stakeholders to address when tackling skill gap issue			Stakeholders: employees, employers, education providers, policymakers. Main action: have common understanding of needed skills and build collaboration and partnerships between stakeholders. Create support for individuals.	
Build understanding	III	Understand employee needs for successful upskilling			Upskilling needs to be adapted to everyone regarding: relevance, organisation & structure, their work context, support from teachers, feedback, social learning.	137 people surveyed

	IV	Understand employers' practices and challenges in managing skill gaps		Recurring skill mapping and skill gap analyses in companies. Leveraging technology to measure skill gaps.	5 priority areas for managers: Skill development initiatives, Knowledge empowerment, Impact and business results, Leadership and culture, and Learning technologies and innovation.	23 people interviewed
	V	Understand companies' workforce readiness towards Industry 5.0			3 company clusters, describe the diverse workforce readiness towards Industry 5.0, based on their skills, training programmes, and workforce resilience: Structured, Ad Hoc, and Adaptive	160 people interviewed
Implement support	VI	Prescribe solution to measure skill gaps and recommend suitable upskilling		Implemented skill-management platform to identify skill gaps for an individual based on their job role and company.	Based on skill gap, skill-management platform recommends suitable training from Ingenjör4.0 modules.	1 skill-matching tool implemented
Evaluation	VII	Evaluate skill-management platform		Challenges in measuring skill gaps accurately.	Recommendations to stakeholders: policymakers ensure enabling conditions, employers and employees integrate the platform in their organisation and continuously improve through feedback loop, education providers and platform designers improve the interoperability and user-focused design.	47 participants surveyed and data gathering in focus groups



# 5

## DISCUSSION

This chapter synthesises the results from the seven appended papers with prior research on the topic to address the three research questions regarding the definition, measurement, and bridging of skill gaps.

This PhD research aimed to gain a deep understanding of the underlying factors affecting skill gaps, explore ways to measure them, identify stakeholders and the actions required to close these gaps, and ultimately develop and test a solution to help bridge the skill gap. In particular, the appended Paper I defined skill gaps and synthesised approaches to measuring them. The appended Paper II identified the stakeholders and their necessary actions. Furthermore, the appended Papers III and IV highlighted the challenges faced by individuals enrolled in an upskilling programme and analysed how skill gaps are managed globally in companies. In the appended Paper V, company clusters were identified to map their workforce readiness concerning their skill gaps towards Industry 5.0, skill initiatives, and workforce resilience. Lastly, the appended Paper VI presents a solution that could assist companies and individuals in identifying their skill gaps through AI-based skill matching, which was tested in the appended Paper VII.

## 5.1 POSITIONING THE THESIS IN RELATION TO PREVIOUS WORK

The increasing urgency for industries to navigate the digital, sustainability, and resilience transitions continues. The productivity paradox (Brynjolfsson, 1993) and the widening skill gap (World Economic Forum, 2025) are urging companies to place people at the centre of industrial transformation. Early in 2025, the European Commission launched the Union of Skills to support quality jobs and skills, and lifelong upskilling opportunities for people (European Commission, 2025b), showing that skills is a top priority. Prior to this in 2021, the European Commission launched the Industry 5.0 initiative, prioritising human development and supporting upskilling to create a sustainable and resilient industry (Breque et al., 2021). In 2019, the World Economic Forum (2019) released a report identifying one of the key challenges for employees' upskilling and reskilling: the high number of people in need of such development, coupled with a lack of evidence-based return on investment for these efforts. The urgency of the skill gap has grown, and demographic changes are becoming more visible. This is also evident in various policy initiatives, such as the Swedish STEM strategy, the Upskill Canada initiative, and the SkillsFuture programme in Singapore, to name just a few notable examples. Skill gaps are prompting large companies to launch initiatives that improve their employees' skills development. These policy initiatives create opportunities for investment in training and upskilling, bridging critical skill gaps in the industry.

However, previous research on this topic lacked a shared understanding of skill gaps, as highlighted in Paper I. The research community has mainly focused on identifying the skills needed in specific fields (Pinzone et al., 2023, Pinzone and Taisch, 2023, Beducci et al., 2024, Shmatko and Volkova, 2020), understanding skill gaps on a conceptual level (McGuinness et al., 2018), or rare prototype solutions to measure skill gaps (Fareri et al., 2023, Fareri et al., 2020). The literature review presented in Paper II identified the need for coordinated strategies among employers, learners, and education providers. Both papers emphasised that, despite this theoretical groundwork in the field, there remains a significant lack of empirical studies documenting how companies manage skill gaps, the challenges they face, and best practices for overcoming them.

The work presented in this PhD thesis addresses these issues. This thesis advances the field by providing qualitative and practical insights directly from industry practitioners. It complements existing theory by analysing not only the strategies in use but also their implementation within companies and the challenges they pose. Unlike previous research, which largely remains at the conceptual level, this thesis uncovers challenges such as resistance to change, employee motivation, and stress arising from ongoing organisational transformation, and thereby combines individual and organisational needs.

The insights and findings from this thesis are vital for addressing the skill gap, as they provide a deeper understanding of stakeholders' needs and offer recommendations for managers, policymakers, and education providers. Although the skill gap remains a complex challenge involving many players, it is now clear which problems must be addressed and which efforts can lead to success. As the title of this thesis suggests, *'Skilling them softly'* is the appropriate approach, meaning that policymakers and

employers need to offer the right incentives and resources to enable employees to upskill gradually in an ever-changing world. To ensure everyone is involved, leaders must create learning ecosystems, foster learning cultures and psychological safety, while education provides appropriate courses. The final point involves collaborating with education providers and providing adequate funding to ensure they continue delivering the necessary training.

## 5.2 DISCUSSING THE RESEARCH QUESTIONS

This subsection discusses the three research questions and how the appended papers contribute to answering them.

### **RQ1: What is a skill gap in the industrial context?**

Being clear when communicating about skill gaps is essential to prevent misunderstandings about which specific gap is being referred to. This was already emphasised in the licentiate thesis (Braun, 2023). However, by including the results from Papers I, II, and IV, there is now a synthesised understanding of skill gaps, the involved stakeholders, and empirical evidence of how managers comprehend the term.

Paper I and Paper II show that skill gaps are a complex issue, caused by the mismatch between the skills employees have and those employers need (Abbasi et al., 2018, Adepoju and Aigbavboa, 2020). McGuinness et al. (2018) point out the different understandings of terms related to skill gaps, and, in Paper I, all these definitions are synthesised into a single definition. The synthesised definition of a skill gap is the lack of the right skills with the right people at the right time (Rikala et al., 2024). Hence, this is the gap between the skills the employer requires and the skills their employees possess. This definition contributes to an improved understanding of the skill gap phenomenon and highlights the key stakeholders involved: employees, employers, and education providers. These stakeholders are continuously challenged by changing business environments and new requirements. Paper II highlights the stakeholders involved in skill gaps and the actions required by them: employees (and other individuals), employers, education providers, and policymakers. The main action these stakeholders should take is to develop a common understanding of the actual skill gaps, and to do so in partnership. This understanding aligns partly with Roth et al. (2022), as the skill gap has both individual and organisational dimensions, requiring consideration of which skills are missing at the individual level and of the organisational level. However, Roth et al. (2022) focuses on the skill gap from an organisational perspective, while this thesis also considers education providers and policymakers, thereby extending the view.

As outlined in Paper IV, managers tend to share a common understanding of skill gaps. For them, a skill gap refers to the difficulty of not having sufficiently skilled employees available, as also defined in Paper I. However, there are differences in the specific skills their employees lack, and in the solutions they prioritise to address these gaps. Most respondents in the study presented in Paper IV identified their gaps in digitalisation and AI skills, although some also mentioned missing skills for sustainability transformation. However, those skills were not mentioned to the expected extent, even though

sustainability and green skills are crucial for industry transformation (Trevisan et al., 2024). This is surprising, since demand for sustainability skills has increased further, and companies need to adapt their workforces to fulfil these new requirements (Pinzone et al., 2024).

Not only could there be different understandings of which skills are needed, but also what a skill is and whether they can be acquired by everyone. This is highlighted in Paper IV, where managers describe efforts to facilitate learning. Some respondents note that not all employees can acquire all skills, as their abilities may limit their capacity to learn specific ones. According to the definition of skill gaps, employees possess certain skills and can acquire the skills their employer requires. Also, the philosophy behind “growth mindset” (Dweck, 2006) is that intelligence can be developed. However, insights from Paper IV indicate that this view should be approached with caution to prevent employees who find it challenging to acquire specific skills from facing unrealistic expectations, which could lead to frustration and the exclusion of some individuals. These insights should rather be used to support or augment these individuals with technologies or other approaches. Methodologies like the Augmented Workforce Canvas (Moencks et al., 2022) help involve employees from the start, understand their needs, and identify how their skills can be further developed or augmented by technology.

To sum up, the skill gap remains a complex issue, influenced by ongoing external factors such as digitalisation and the global crisis, which are causing changes for employees, employers, and education providers. The main issue is understanding that skill gaps are the difference between the skills employees possess and the skills employers require, and that there are various skills currently lacking. It’s also beneficial to consider whether these skills can be learned or if there could be other solutions.

## **RQ2: How can skill gaps be measured?**

McGuinness and Ortiz (2016) clearly emphasise the importance of measuring employees’ skill gaps to prevent inefficient upskilling investments. Additionally, Paper III highlighted the importance of adapting learning content to the individual. To do that, it is essential to understand the person’s skill gap. Previous literature has shown that there is no well-established method for systematically measuring skill gaps, as outlined in Paper I. In some reviewed articles, skill gaps were measured by first establishing a skill framework for a specific job role or domain, including all necessary skills, their definitions, and descriptions of skill levels (Babic et al., 2022, Trevisan et al., 2024, Pinzone et al., 2024, Pinzone et al., 2023). This framework was then used to benchmark employees and identify skill gaps. In the reviewed literature, the skill framework was often converted into a self-assessment survey sent to employees, who then estimated their skill levels (Do et al., 2023). In some instances, managers also performed this assessment by estimating their employees’ skill levels (Zheng and Shi, 2022). However, a challenge associated with bias arises when assessing one’s own skills (McGuinness and Ortiz, 2016). This was also confirmed in Paper VII, which highlighted the need to develop a solution on the skill development platform that reduces the risk of self-assessment bias.

Previously, skill gaps were seen as the difference between the supply and demand of skills, meaning the supply of skills is defined by the skills a person has, and the demand by the skills a person should have (Ansari et al., 2020, Khobreh et al., 2019). This thesis takes this knowledge a step further by applying the concept to a solution for measuring the skill gaps presented in Paper VI. A virtual skills framework is created through data analysis of skill and job descriptions in databases like LinkedIn, which then suggests relevant skills to users so they and their managers can assess these skills. Another solution that aims at matching suitable skills and training to users is presented by Fareri et al. (2023). In their tool, patents are analysed to suggest the impacts of trends on job transformation and new skills to learn. These solutions yield comparable outcomes but differ in the data they use to predict a person's skill needs. The solution presented in Paper VI uses a person's job role and the company they work for to determine which skills they should have, based on LinkedIn and other databases. Then, the expected skills for that person are used in a self-assessment, revealing the person's skill gaps. So far, there is a lack of empirical data on the success of the tool in Paper VI, the tool by Fareri et al. (2023), and other commercial tools for measuring skill gaps, making it hard to say which tool would be best for measuring skill gaps.

Paper IV offered insights into how the interviewed companies evaluate their skill gaps and the challenges they encounter. Some respondents indicated that their organisations establish skill frameworks that specify the skills required for particular job roles or sectors, consistent with the findings from the literature review outlined in Paper I (Do et al., 2023). However, the process is described as somewhat difficult because the number of skills within a company is large and the skill framework is constantly evolving (Paper IV). Respondents explained that they have processes aligned with their annual performance reviews to address employees' skill gaps. Additionally, some respondents mentioned the technologies their companies use to organise employees' skills and learning progress. However, respondents note that skill management tools are only as good as user adoption and data input. If employees and managers don't consistently enter data, the current learning status and skill gaps are inaccurate (Braun et al., 2025b).

Additionally, respondents notice that self-rating bias impacts the results of skill assessments and can lead to misconceptions about training needs (Paper IV). Additionally, the ongoing transformation of industry makes it more challenging to maintain an up-to-date skill gap assessment tool that delivers suitable recommendations. The factors of increased user input and tool usage, self-assessment bias, and continuous updating are essential to consider. They are also highlighted in Paper VII, where the skill gap management tool presented in Paper VI was evaluated. Fareri et al. (2023) compares a couple of existing profiling tools and concludes that there is still work to do to improve their success, i.e. to achieve a standardised source for data, to cover a wide range of skills, and to match skills needed in the future, not only the ones relevant right now.

A skill gap assessment of Industry 5.0 skills in Europe is presented in Paper V through the analysis of the questionnaire's skill-related answers. Paper V outlines, among other things, Europe's Industry 5.0 skill gaps, measured through survey-based interviews that ask about specific skills needed for Industry 5.0 and respondents' estimates of employees' skill levels in their companies. This assessment provides a useful indication

and allows us to cluster companies based on their answers. In addition, this assessment can help practitioners understand which skills are relevant to improving their Industry 5.0 adoption.

The solution presented in Paper VI and evaluated in Paper VII is designed to address the challenge of constantly evolving industry needs, while also catering to the individual requirements of employees, as required in Paper III. This solution utilises available, continually updated databases to provide an algorithm with relevant data to assess a person's skill gap. The implementation and presentation of the solution in Paper VI rely on LinkedIn data to obtain current information on job roles and associated skills. Furthermore, it employs a widely recognised skills taxonomy, namely the European ESCO database. Although the skill-matching platform appeared to simplify measuring skill gaps, the evaluation revealed otherwise. For instance, integrating the platform with existing LMS systems in companies poses challenges, and users are often hesitant to trust an AI with their skill development. Additionally, the bias inherent in self-assessment also plays a role. Even when the AI suggests the skills a person needs, the user still performs a self-assessment of those skills. The bias of self-assessment impacts the results and therefore, should be interpreted with care (McGuinness and Ortiz, 2016).

### **RQ3: How can skill gaps be bridged?**

In discussions and initiatives, the emphasis on solutions to bridge skill gaps often focuses too heavily on the pipeline: "How can we get more young students to study in the STEM field?" (Utbildningsdepartementet, 2025), rather than on the current industry workforce that lacks the necessary skills. Many people believe the skill gap is mainly caused by a shortage of young people entering the STEM field, but it is also due to the overall low number of young people. This lack of shared understanding results in insufficient efforts to upskill the existing workforce (World Economic Forum, 2025). Recognising the industry skill gap as a challenge influenced by both the incoming pipeline and the skills of those already available helps address it. Some of the managers interviewed in the study in Paper IV highlight that they focus on both hiring and upskilling to bridge their skill gaps.

The third research question links different elements to understand how to effectively bridge industrial skill gaps. Skill gaps can be addressed by involving diverse stakeholders, as shown in previous literature and outlined in Paper II. Stakeholders include employees, students, job seekers, employers, education providers, policymakers, and researchers. The main responsibilities of these stakeholders are to develop a shared understanding of the skill gap and to build partnerships for collective action. However, they also need to act individually. For example, education providers should update their curricula to match current industrial demands, which requires ongoing discussions with industry leaders (Braun et al., 2024b). This aligns with the scenario suggested by Foka et al. (2025) in which education providers are agile and constantly develop their curricula to meet industry needs. This necessitates continuous dialogue between education providers and industry. As highlighted by Vuoriainen et al. (2025), key success factors for academia-industry partnership include commitment, clarity, communication, commonality, continuity, and confidence. Furthermore, employers must create environments that enable employees to access proper training and time, while

employees should proactively identify their skill gaps and pursue continuous learning (Braun et al., 2024b).

These insights, identified through a literature review, were further investigated in the studies presented in Papers III- VII. Paper III focused on employees' individual learning needs (Braun et al., 2023). To motivate people and sustain their interest in learning, the right circumstances must be in place. Paper III demonstrated how these needs can vary significantly from person to person. The skills or learning content relevant to one individual might be unnecessary for another, especially considering their specific work context and background. Furthermore, employees have many other tasks and personal commitments, making it crucial to organise the training flexibly. Additionally, receiving feedback from teachers is vital to maintaining high engagement in learning, as was also highlighted by Dweck (2006) as an important aspect in developing a growth mindset. Finally, social learning can encourage learners to participate more actively in their learning.

What managers can do to bridge skill gaps was addressed in Paper IV. This resulted in five key priority areas for management to bridge skill gaps: 1) promote and support Skill development initiatives, 2) enhance the Knowledge empowerment of the workforce by motivating employees to learn, 3) measure skills-related KPIs to understand the Impact and business results of learning initiatives, 4) create Leadership and culture that promotes learning, and 5) leverage Learning technologies and innovation to offer individualised learning and manage upskilling smoothly and in a motivating way (Braun et al., 2025b). The need to build an organisation that motivates employees to learn and offers support systems was previously brought up by Boeren (2023), and now confirmed and emphasised by the skill bridge study (Braun et al., 2025b). There is a need to research motivation for learning in a fast-changing world and to find ways to support employees. For instance, the benefits of prosocial motivation (Grant, 2008) could be enhanced by showing employees how their learning and new skills would benefit their organisation, their customers, or society as a whole.

Technologies have the potential to improve upskilling and help employees maintain a lifelong learning journey. One of the main challenges identified in Paper III to close skill gaps was that each individual needs personalised support. Given that nearly 44% of the global workforce requires upskilling (World Economic Forum, 2023), and providing personalised support to each would require significant resources, a technological solution to identify skill gaps is essential to replace human support. People find it difficult to know what to learn and where to find suitable learning opportunities.

The implementation and evaluation of a tool that identifies individual skill gaps and recommends new learning are presented in Papers VI and VII. The studies reveal the significant potential of this kind of solution to help employers manage their employees' upskilling and support them in finding their individual learning paths. However, during the test and evaluation, several challenges arose. Therefore, we present recommendations to improve the usability and impact of such solutions. To start with, platform providers and education providers improve the interoperability and user-focused design. Employers and employees build commitment and provide continuous feedback to improve the platform. Lastly, policymakers provide the enabling conditions,

for instance, by funding pilots to test digital learning platforms, ensuring inclusivity, and providing new ways to acknowledge alternative learning paths.

Furthermore, to effectively bridge skill gaps, companies should build workforce resilience to successfully transform their businesses in line with Industry 5.0 principles (Paper V). As they transition towards Industry 5.0, where human-centricity and skills are fundamental, companies demonstrate varying levels of workforce readiness. The Structured company cluster has strong skills and training for its workforce. However, they could develop emerging skills, such as AI literacy. The Adaptive cluster includes companies of all sizes but is most prominently represented among startups. These companies excel in skills despite low investment in training programs. Managers in Adaptive firms should be resource-efficient with training investments and align them with business goals. Additionally, policymakers need to ensure these companies have sufficient resources to remain competitive and to expand. The Ad hoc cluster mainly comprises mid-cap businesses and performs weaker in nearly all variables compared to the other two clusters, except in cybersecurity and digital skills training. These companies risk falling behind or even losing their competitiveness. Ad hoc companies should establish clear structure for learning and invest in upskilling. Policymakers should create incentives for these organisations to foster learning cultures and ecosystems that promote employee development.

### **5.3 CONTRIBUTION**

This subsection describes the contribution this thesis makes to theory, practice, and society.

#### **Theoretical contribution**

This thesis's theoretical contribution is an understanding of skill gaps, offering a nuanced, multi-stakeholder perspective grounded in the literature and empirical data. Prior research often frames skill gaps as a macroeconomic issue and a hurdle to ongoing transformations (Brynjolfsson et al., 2020, González Chávez et al., 2023). Other studies related to skill gaps have focused on methods to understand and measure them, for instance, by framing skill gaps as a disparity between supply and demand of skills and developing ways to quantify these skills and forecast changing skill needs (Khobreh et al., 2019, Fareri et al., 2023, Solinas et al., 2020). Additionally, this work examines how skill gaps are experienced and addressed in practice within companies, drawing on the perspectives of employees, managers, and HR professionals. The work establishes a set of visualisations to understand these issues better and identify future research directions. It also discusses the challenges practitioners face and proposes a solution for matching learners to suitable learning paths. By evaluating skill management tool, the thesis makes one of the first empirical contributions in the field.

The proposed Skill Bridge extends previous fragmented literature with in-depth qualitative data and identifies five critical dimensions that shape skill gap management in industrial settings: Skill initiatives, Knowledge empowerment, Impact and business results, Learning and culture, and Learning technologies and innovation (Braun et al., 2025b). This thesis also builds on and contributes to organisational learning theory,

lifelong learning, and human-centric industrial transformation models (Romero et al., 2020), by emphasising managerial, technological, and psychological aspects of skill development often overlooked in existing frameworks.

### **Practical contribution**

Practically, the thesis provides companies and policymakers with a set of recommendations. Policymakers receive guidance on companies' diverse skill-development needs, based on company clustering. The Skill Bridge can be used as a tool for strategic reflections, helping organisations to structure their learning ecosystems, identify bottlenecks in learning motivation and engagement, and make strategic decisions about technologies to support continuous learning. The findings highlight concrete challenges practitioners face – such as change resistance, low engagement with digital tools, and bias in self-assessments – as well as successful practices, such as mentoring, communities of practice, and LMS (Braun et al., 2025b). The thesis's contributions to employees are to help them understand their role in addressing the skill gap challenge, act, and find their personal motivation to learn.

The insights are directly applicable to HR departments, learning designers, and leadership teams seeking to implement skill-matching solutions to enhance their workforce's adaptability in an era of constant transformation, helping employees find suitable learning paths and motivation, and continue upskilling.

### **Societal contribution**

Societally, this work contributes to the broader goal of creating a human-centric, inclusive, and resilient industry. Unpacking how learning can be enabled within companies provides insights into how individuals can be better supported, e.g., by mitigating stress, disengagement, and marginalisation that often accompany industrial transformations.

Although many recent initiatives, such as the European Union of Skills and the Swedish STEM strategy, highlight the urgency of developing people's skills, research on skill gaps remains limited. By emphasising the need to democratise learning and share the responsibility for lifelong learning among employees, employers, and education providers, this thesis supports the vision of Industry 5.0, where human-centricity and social sustainability are central. In doing so, it helps bridge skill gaps and gaps between technological, economic, and social transformations. As previously discussed, the productivity paradox (Brynjolfsson et al., 2020) hampers the realisation of the expected economic benefits of new technologies because intangible assets, like skilled workers, are not yet in place. This thesis contributes to bridging the gap between technological and human advancements.

## **5.4 METHODOLOGICAL REFLECTIONS**

This subsection contains the methodological reflections, including my personal bias and the reflections on DRM. The discussion follows the guiding questions of: *What was the mission? What was done? How did it go? What could have been done differently?*

The mission was to address skill gaps arising in industrial contexts, understand stakeholders' needs, and test a skill-matching solution. DRM was selected because it provides a systematic approach to addressing problems and designing solutions for practitioners (Blessing and Chakrabarti, 2009). It also allows flexibility in how the solution might be presented, whether as a physical product or a digital artefact. Additionally, DRM involves both theoretical and practical steps that align well with the research questions and the overall goal of understanding and solving the problem. The four steps of DRM—Research Clarification, Descriptive Study I, Prescriptive Study, and Descriptive Study II—offer a logical sequence that combines theoretical research with empirical data collection to thoroughly understand the problem and evaluate a solution (Blessing and Chakrabarti, 2009). The Research Clarification involved reviewing relevant literature to understand what had been done in the field so far. This clarified that there was no clear understanding of the term “skill gap,” nor a consensus on the stakeholders involved or the actions they must take to close skill gaps. This step helped identify key stakeholders and the challenges faced in the field. These insights were deepened in Descriptive Study I, which comprised three studies: one with employees enrolled in an online upskilling programme, one with managers handling skill gaps in their companies, and one with both employees and managers to assess their Industry 5.0 workforce readiness in terms of skills, upskilling programmes, and human capital resilience. This step was essential as it provided a better understanding of stakeholders' needs and challenges. One prominent challenge identified was measuring individual skill gaps and finding appropriate learning paths with relevant content tailored to their context. These insights from both theory and practice underscore the need to design a solution that helps individuals and managers identify employees' skill gaps and recommend suitable learning options. The solution was implemented through the Prescriptive Study. Finally, the solution was evaluated via focus groups and feedback sessions, providing evidence of its practicality and highlighting areas for improvement.

Overall, the methodology helped maintain a clear link between the original problem and the design of a relevant solution, ensuring that an impact could be achieved through this research. This is a clear strength of DRM, since following the steps forces the researcher to keep thinking of the original problem and not lose track in a fast-changing research field. Many mixed-methods were needed to triangulate the data, even though the mixed-methods approach also leads to lower validity.

Some limitations became apparent. The structured stages of DRM can, in this rapidly evolving research area, seem too linear. With several ongoing projects running in parallel and feeding into this work, problem definitions and solutions develop more simultaneously. In practice, this meant that work oscillated between gaining a better understanding of the problem and already implementing testable solutions. While DRM provides iteration loops, its structure can still feel relatively rigid compared to the rapid pace of research. The skill gap issue is affected by shifting technologies, politics, geopolitical threats, pandemics, policy decisions, and other factors that can change significantly within months. In this environment, some parts of agile project management could offer additional benefits, such as shorter iteration cycles, frequent stakeholder check-ins, and the flexibility to reprioritise goals. Even though DRM focused strongly on problem and solution, it could have been further complemented by agile practices to improve responsiveness in this fast-changing field. Moreover, DRM

emphasises the development of a solution, which could risk the theoretical contribution and undermine the academic part of the research.

From a personal bias perspective, I must acknowledge my strong motivation to create a solution that effectively guides employees in their upskilling. This motivation led me to prioritise the practical contribution of this work over purely theoretical contributions. Although this aligns with my pragmatist epistemology, it could be seen as a limitation in contributing to academic theory. In hindsight, integrating a more explicit theoretical framework alongside the design research steps could have enhanced the theoretical contribution. If I were to repeat the study, I would allocate more time to comparing existing theories and developing new ones during the solution development phase. However, in this fast-changing research area, it didn't seem suitable to measure data at a very detailed level, e.g., defining skills for a specific job role, but there was a need to understand what is going on, which aligned with the pragmatic approach.

Additionally, I would have considered developing personas early on to represent a wider range of stakeholder types. This would have helped to understand the challenges and needs of different stakeholder groups. In this work, there is no distinction between employees, for example. Nonetheless, DRM proved to be a suitable methodology for addressing the complex challenge of bridging skill gaps, as it is adaptable to the context and effectively addresses a real-world problem.

## **5.5 FUTURE RESEARCH**

While this research provides valuable insights into bridging skill gaps, several opportunities for future research remain. Future research could expand on the findings by testing the skill-matching solution with a more diverse, larger group of learners and by employing longitudinal research designs to examine the impact of such solutions on learners and society.

First, it would be essential to test and refine the proposed skill-matching solution further. Although the focus groups from two different contexts provided valuable feedback on potential improvements, a larger and more diverse test group is necessary, as results may vary considerably depending on the individuals involved. Additionally, other skill-matching solutions exist, and there is limited understanding of their strengths and weaknesses. Therefore, future research should compare several solutions based on usability, recommendation quality, and platform integration.

Second, longitudinal studies could help examine the long-term effects of implementing the management practices outlined in the skill bridge and skill-matching solutions on employee development, retention, career progression, and organisational performance. Such research could also help prevent the effects of skill gaps, such as the exclusion of certain groups of people.

Thirdly, further research could investigate the impact of skill gaps on society and explore how solutions for addressing these gaps might support regional, national, or European strategies for industrial resilience. For example, when a region commits to providing a company with appropriately skilled talent once its factory is fully developed, such skill-

matching solutions could help identify who needs which type of upskilling or reskilling.

Lastly, the rapidly changing nature of skill gaps could be studied in a more agile manner. Shorter iteration cycles would ensure the project remains continuously aligned with society's current needs. Within just five years of this project, there have been significant events such as the COVID-19 pandemic, large-scale initiatives to build battery factories, rising urgency of the climate crisis, political instability, geopolitical threats and war, and inflation — to name some of the most impactful happenings for industry. These events can influence workforce demand in just a few months, weeks, or even days. These impacts need to be considered continuously, and therefore, research could be more agile.

# 6

## CONCLUSION

*Wir schaffen das! (We can do it!) – Angela Merkel*  
*Yes, we can! – Barack Obama*

*Skilling Them Softly* maintains a hopeful and caring vision for the future of industrial learning. The title echoes the song *Killing Me Softly*, in which an internal process unfolds quietly and slowly. In today's industrial transformation, skill needs evolve gradually rather than overnight. Without human intervention, this slow and silent process risks leaving workers behind. *Skilling Them Softly* turns this idea around by proposing a human-centred solution in which upskilling happens continuously, with shared responsibility, and with individual human needs in mind. That way ensures that humans remain vital and valued in the future industry.

This thesis shows that skill gaps are complex but can be effectively closed by developing learning ecosystems that support individuals throughout their working lives. Through theoretical and empirical research, it identifies the key stakeholders and their roles in shaping sustainable skills systems. These stakeholders are employees, employers,

education providers, and policymakers. To bridge skill gaps, stakeholders must collaborate and perform their roles effectively. In this way, the industry will benefit from a skilled workforce that fosters resilience and sustainability.

The mission of this work was to put humans at the centre and to understand how they could be supported in addressing skill gaps. The studies contributing to this thesis mainly leverage interviews and qualitative surveys to highlight what stakeholders must do to build a learning ecosystem that motivates individuals to learn continuously, thereby equipping the workforce with appropriate skills.

The key insights from the thesis are captured in the *skill bridge*, which recommends practices and highlights challenges in managing skill gaps. Moreover, the thesis presents three company profiles that describe their workforce readiness for Industry 5.0. Furthermore, the work highlights key aspects of creating motivating learning for employees enrolled in an upskilling programme. To overcome the challenge of measuring and bridging skill gaps, the thesis presents a solution to identify them and recommend suitable learning for individuals. Finally, the results include recommendations for further developing solutions that measure skill gaps and match people to courses.

The thesis contributes to both theory and practice by offering a framework for managers to coordinate upskilling actions, recommendations for policy design, organisational learning strategies, and technological solutions that tailor learning to individual needs. The research shows that skill gaps cannot be addressed solely through technology; people involved require support and care.

# REFERENCES

- ABBASI, F., CHAUDHRY, A. & BIBI, N. 2018. Analysis of skill gap for business graduates: managerial perspective from banking industry. *Education + Training*, 60.
- ABELE, E., METTERNICH, J., TISCH, M., CHRYSOLOURIS, G., SIHN, W., ELMARAGHY, H., HUMMEL, V. & RANZ, F. 2015. Learning Factories for Research, Education, and Training. *Procedia CIRP*, 32, 1-6.
- ADAMS, N. E. 2015. Bloom's taxonomy of cognitive learning objectives. *J Med Libr Assoc*, 103, 152-3.
- ADEPOJU, O. & AIGBAVBOA, C. 2020. Assessing knowledge and skills gap for construction 4.0 in a developing economy. *Journal of Public Affairs*, 21.
- ANSARI, F., HOLD, P. & KHOBREH, M. 2020. A knowledge-based approach for representing jobholder profile toward optimal human-machine collaboration in cyber physical production systems. *Elsevier*.
- ARGYRIS, C. & SCHÖN, D. A. 1978. *Organizational learning: A theory of action perspective*, Addison-Wesley Publishing Company, 1978.
- ASCHENBRENNER, D., GROS, J., FANGEROW, N., WERNER, T., COLLOSEUS, C. & TAHA, I. 2023. Recyclebot – using robots for sustainable plastic recycling. *Procedia CIRP*, 116, 275-280.
- AUTOR, D. H. 2015. Why Are There Still So Many Jobs? The History and Future of Workplace Automation. *Journal of Economic Perspectives*, 29, 3-30.
- BABIC, M., BILLEY, A., NAGER, M. & WUEST, T. 2022. Status Quo of Smart Manufacturing Curricula offered by ABET accredited Industrial Engineering programs in the US. *Manufacturing Letters*, 33, 944-951.
- BEDUCCI, E., ACERBI, F., PINZONE, M. & TAISCH, M. 2024. Unleashing the role of skills and job profiles in circular manufacturing. *Journal of Cleaner Production*, 449, 141456.
- BENGMARK, S. 2023. Teaching Competencies. In: DUBLIN, T. U. (ed.) *European Society for Engineering Education (SEFI)*.
- BLESSING, L. & CHAKRABARTI, A. 2009. *DRM, a Design Research Methodology*.
- BOEREN, E. 2023. Conceptualizing Lifelong Learning Participation. Theoretical Perspectives and Integrated Approaches. In: PUBLIKATION, W. (ed.) *Internationales Jahrbuch der Erwachsenenbildung 2023. Researching Participation in Adult Education*. Bielefeld.
- BOKRANTZ, J., SKOOGH, A., BERLIN, C., WUEST, T. & STAHRÉ, J. 2020. Smart Maintenance: an empirically grounded conceptualization. *International Journal of Production Economics*, 223, 107534.
- BRAUN, G. 2023. *Towards Bridging Skill Gaps for the Future Industrial Workforce*, Department of Industrial and Materials Science, Chalmers University of Technology.
- BRAUN, G., BOKINGE, M., ROSÉN, B. G., SYBERFELDT, A. & STAHRÉ, J. Mastering Industry's Skill Gap - Matching Employee Needs with New Learning Challenges. 2024 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 15-18 Dec. 2024 2024a. 668-672.
- BRAUN, G., JÄRVINEN, M., STAHRÉ, J. & HÄMÄLÄINEN, R. 2022a. Motivational Challenges of Engineers Participating in an Online Upskilling Program. In: FOTARIS, P. & BLAKE, A. (eds.) *ECEL 2022 : Proceedings of the 21st European Conference on e-Learning*. Brighton, UK: Academic Conferences International.
- BRAUN, G., KRETSCHMER, M., BOKINGE, M., SINGER-COUDOUX, K., ROSÉN, B.-G. & STAHRÉ, J. Evaluating a Skill Management Platform – Towards an Upskilling System for Large and Small Companies. In: KHALID, S., ed. *European Conference on e-Learning, 2025a Technical University of Denmark (DTU), Denmark*.
- BRAUN, G., RÄTY, P., BOKINGE, M., RIKALA, P., HÄMÄLÄINEN, R., SYBERFELDT, A. & STAHRÉ, J. 2025b. The skill bridge – A global qualitative analysis of skill gap management. *Journal of Environmental Management*, 395, 127738.
- BRAUN, G., RIKALA, P., JÄRVINEN, M., HÄMÄLÄINEN, R. & STAHRÉ, J. 2024b. Bridging Skill Gaps

- A Systematic Literature Review of Strategies for Industry. *Swedish Production Symposium. Sustainable Production through Advanced Manufacturing, Intelligent Automation and Work Integrated Learning* ed.
- BRAUN, G., STAHR, J. & HÄMÄLÄINEN, R. 2022b. Skills Matching for a Greener Industry 4.0 – a Literature Review. *Swedish Production Symposium*.
- BRAUN, G., STAHR, J., ROSÉN, B.-G. & BOKINGE, M. 2023. Ingenjör4.0 – A National Upskilling Programme to Bridge Industry's Skill Gap. *Procedia CIRP*, 120, 1286-1291.
- BREQUE, M., DE NUL, L. & PETRIDIS, A. 2021. Industry 5.0 - Towards a sustainable, human-centric and resilient European industry. *Policy brief European Commission*.
- BRYNJOLFSSON, E. 1993. The Productivity Paradox of Information Technology. *Commun. ACM*, 36, 66-77.
- BRYNJOLFSSON, E., LI, D. & RAYMOND, L. 2023. Generative AI at Work. Available: <https://ui.adsabs.harvard.edu/abs/2023arXiv230411771B> [Accessed April 01, 2023].
- BRYNJOLFSSON, E., ROCK, D. & SYVERSON, C. 2020. The Productivity J-Curve: How Intangibles Complement General Purpose Technologies. *NBER Working Paper*, 25148.
- CAO, H., RIVERA, F. G., SÖDERLUND, H., BERLIN, C., STAHR, J. & JOHANSSON, B. 2025. Human-centered design of VR interface features to support mental workload and spatial cognition during collaboration tasks in manufacturing. *Cognition, Technology & Work*, 27, 467-485.
- CHARI, A., DESPEISSE, M., JOHANSSON, B., MORIOKA, S., GOHR, C. F. & STAHR, J. 2024. Resilience compass navigation through manufacturing organization uncertainty – A dynamic capabilities approach using mixed methods. *CIRP Journal of Manufacturing Science and Technology*, 55, 375-389.
- CHRYSSOLOURIS, G., MAVRIKIOS, D. & MOURTZIS, D. 2013. Manufacturing Systems: Skills & Competencies for the Future. *Procedia CIRP*, 7, 17-24.
- DELOITTE 2016. The new organization: Different by design. In: PRESS, D. U. (ed.) *Global Human Capital Trends*.
- DO, H.-D., TSAI, K.-T., WEN, J.-M. & HUANG, S. K. 2023. Hard Skill Gap between University Education and the Robotic Industry. *Journal of Computer Information Systems*, 63, 24-36.
- DRAGHI, M. 2024. The future of European competitiveness. European Commission.
- DWECK, C. S. 2006. *Mindset: The new psychology of success*, Random House.
- EASTERBY-SMITH, M., THORPE, R., JACKSON, P. R. & JASPERSEN, L. J. 2018. *Management & Business Research*, Sage Publications Ltd.
- EDMONDSON, A. 1999. Psychological Safety and Learning Behavior in Work Teams. *Administrative Science Quarterly*, 44, 350-383.
- EDMONDSON, A. C. & LEI, Z. 2014. Psychological safety: The history, renaissance, and future of an interpersonal construct. *Annual Review of Organizational Psychology and Organizational Behavior*, 1, 23-43.
- EUROPEAN COMMISSION. 2021. *Industry 5.0* [Online]. Available: [https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/industry-50\\_en#industry-50-award](https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/industry-50_en#industry-50-award) [Accessed 1 april 2025].
- EUROPEAN COMMISSION 2025a. A Competitiveness Compass for the EU. *COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS*.
- EUROPEAN COMMISSION 2025b. Union of Skills communication. In: *DIRECTORATE-GENERAL FOR EMPLOYMENT*, S. A. A. I. (ed.).
- EUROPEAN COMMISSION, S.-G. 2020. European Commission Report on the Impact of Demographic Change. eurostat.
- EUROPEAN ROUND TABLE FOR INDUSTRY 2024. Competitiveness and Industry Benchmarking Report. In: *COUNSEL*, G. (ed.).
- FARERI, S., APREDA, R., MULAS, V. & ALONSO, R. 2023. The worker profiler: Assessing the digital skill gaps for enhancing energy efficiency in manufacturing. *Technological Forecasting and Social Change*, 196, 122844.
- FARERI, S., FANTONI, G., CHIARELLO, F., COLI, E. & BINDA, A. 2020. Estimating Industry 4.0

- impact on job profiles and skills using textmining. *Elsevier*.
- FOKA, A., GULLIKSEN, J., HEINTZ, F. & LOUTFI, A. 2025. *ADVANCED DIGITAL SKILLS 2035 – FUTURE SCENARIOS AND IMPLICATIONS FOR POLICY MAKING ON HIGHER EDUCATION FOR DIGITAL SKILLS AND LIFELONG LEARNING*.
- FREY, C. B. & OSBORNE, M. A. 2013. The future of employment: How susceptible are jobs to computerization? *Oxford Martin Programme on Technology and Employment*.
- GONZÁLEZ CHÁVEZ, C. A., UNAMUNO, G., DESPEISSE, M., JOHANSSON, B., ROMERO, D. & STAHR, J. 2023. Analyzing the risks of digital servitization in the machine tool industry. *Robotics and Computer-Integrated Manufacturing*, 82, 102520.
- GOVERNMENT OF CANADA. 2025. *Upskilling for Industry Initiative* [Online]. Available: <https://ised-isde.canada.ca/site/upskilling-industry-initiative/en?wbdisable=true#:~:text=About%20the%20call%20for%20applications,via%20a%20single%20lead%20recipient>. [Accessed 10 July 2025].
- GOVERNMENT OF SINGAPORE. 2023. *SkillsFuture Singapore* [Online]. Available: <https://www.skillsfuture.gov.sg/> [Accessed 19 2023].
- GOVERNMENT OF SINGAPORE. 2025. *SkillsFuture Year-In-Review 2024: Learners Shift to More Career-Relevant Training with the SkillsFuture Level-Up Programme* [Online]. Available: <https://www.ssg.gov.sg/newsroom/skillsfuture-year-in-review-2024> [Accessed 9 April 2025].
- GRANT, A. & PARKER, S. 2009. 7 Redesigning Work Design Theories: The Rise of Relational and Proactive Perspectives. *The Academy of Management Annals*, 3, 317-375.
- GRANT, A. M. 2008. Does intrinsic motivation fuel the prosocial fire? Motivational synergy in predicting persistence, performance, and productivity. *J Appl Psychol*, 93, 48-58.
- GURUGE, D. B., KADEL, R. & HALDER, S. J. 2021. The State of the Art in Methodologies of Course Recommender Systems—A Review of Recent Research. *Data*, 6, 18.
- HÄMÄLÄINEN, R., DE WEVER, B., NISSINEN, K. & CINCINNATO, S. 2019. What makes the difference – PIAAC as a resource for understanding the problem-solving skills of Europe's higher-education adults. *Computers & Education*, 129, 27-36.
- HATTIE, J. & TIMPERLEY, H. 2007. The Power of Feedback. *Review of Educational Research*, 77, 81-112.
- INGENJÖR4.0. 2023. *Ingenjör4.0* [Online]. Available: <https://www.ingenjor40.se> [Accessed 10 July 2023].
- IPSEN, C., VAN VELDHOVEN, M., KIRCHNER, K. & HANSEN, J. P. 2021. Six Key Advantages and Disadvantages of Working from Home in Europe during COVID-19. *International Journal of Environmental Research and Public Health* [Online], 18.
- KHOBREH, M., ANSARI, F. & SEIDENBERG, U. 2019. A knowledge-based approach for linking workforce experience and labor productivity in smart factory industry 4.0. *TAKE Conference*.
- KIRKPATRICK, D. L. & KIRKPATRICK, J. D. 2006. *Evaluating Training Programs: The Four Levels*, Berrett-Koehler Publishers.
- KLIMAT- OCH NÄRINGSGLIVSDEPARTEMENTET 2025. Sveriges industristrategi: för en teknikledande och konkurrenskraftig industri i en ny omvärld. In: REGERINGSKANSLIET (ed.).
- KUMAR, R. & GANAPATHY, V. 2020. Bio-Inspiring Learning Style Chatbot Inventory Using Brain Computing Interface to Increase the Efficiency of E-Learning. *IEEE Access*, PP, 1-1.
- LENG, J., SHA, W., WANG, B., ZHENG, P., ZHUANG, C., LIU, Q., WUEST, T., MOURTZIS, D. & WANG, L. 2022. Industry 5.0: Prospect and retrospect. *Journal of Manufacturing Systems*, 65, 279-295.
- LINDEN, G., SMITH, B. & YORK, J. 2003. Amazon.com recommendations: item-to-item collaborative filtering. *IEEE Internet Computing*, 7, 76-80.
- MANPOWERGROUP 2024. Global Talent Shortage. In: MANPOWER, EXPERIS MANPOWERGROUP & TALENT SOLUTIONS MANPOWERGROUP (eds.).
- MCGUINNESS, S. & ORTIZ, L. 2016. Skill gaps in the workplace: measurement, determinants and impacts. *Industrial Relations Journal*, 47, 253-278.
- MCGUINNESS, S., POULIAKAS, K. & REDMOND, P. 2017. How Useful is the Concept of Skills Mismatch? International Labour Organization: Skills and Employability Branch.
- MCGUINNESS, S., POULIAKAS, K. & REDMOND, P. 2018. Skills mismatch: Concepts, measurement

- and policy approaches. *Journal of Economic Surveys*, 32, 985-1015.
- MCKINSEY GLOBAL INSTITUTE 2024. A new future of work: The race to deploy AI and raise skills in Europe and beyond. In: HAZAN, E., MADGAVKAR, A., CHUI, M., SMIT, S., MAOR, D., SINGH DANDONA, G. & HUYGHUES-DESPOINTE, R. (eds.).
- MIT TECHNOLOGY REVIEW INSIGHTS 2022. Building the necessary skills for digital transformation. In: PROUST, D. (ed.).
- MOENCKS, M., ROTH, E., BOHNÉ, T., ROMERO, D. & STAHRÉ, J. 2022. Augmented Workforce Canvas: a management tool for guiding human-centric, value-driven human-technology integration in industry. *Computers & Industrial Engineering*, 163, 107803.
- NONAKA, I. & TAKEUCHI, H. 1995. *The Knowledge-creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press.
- ONAH, D., SINCLAIR, J. & BOYATT, R. Dropout Rates of Massive Open Online Courses: Behavioural Patterns. 6th International Conference on Education and New Learning Technologies, 2014 Barcelona, Spain.
- OSBORNE, S. 2020. *The Upskilling Imperative: 5 Ways to Make Learning Core to the Way We Work*, McGraw Hill.
- PALETTE SKILLS. 2025. *Unleashing Canada's potential* [Online]. Available: <https://paletteskills.org/upskill-canada/about-upskill-canada> [Accessed 9 april 2025].
- PINZONE, M., BRAUN, G. & STAHRÉ, J. Contemporary and Future Manufacturing – Unveiling the Skills Palette for Thriving in Industry 5.0. In: THÜRER, M., RIEDEL, R., VON CIEMINSKI, G. & ROMERO, D., eds. *Advances in Production Management Systems. Production Management Systems for Volatile, Uncertain, Complex, and Ambiguous Environments, 2024// 2024 Cham*. Springer Nature Switzerland, 444-456.
- PINZONE, M., FANTINI, P. & TAISCH, M. 2023. Skills for Industry 4.0: a structured repository grounded on a generalized enterprise reference architecture and methodology-based framework. *International Journal of Computer Integrated Manufacturing*, 1-20.
- PINZONE, M. & TAISCH, M. Towards a Circular Manufacturing Competency Model: Analysis of the State of the Art and Development of a Model. In: ALFNES, E., ROMSDAL, A., STRANDHAGEN, J. O., VON CIEMINSKI, G. & ROMERO, D., eds. *Advances in Production Management Systems. Production Management Systems for Responsible Manufacturing, Service, and Logistics Futures, 2023// 2023 Cham*. Springer Nature Switzerland, 189-199.
- PONTES, J., GERALDES, C. A. S., FERNANDES, F. P., SAKURADA, L., RASMUSSEN, A. L., CHRISTIANSEN, L., HAFNER-ZIMMERMANN, S., DELANEY, K. & LEITÃO, P. 2021. Relationship between Trends, Job Profiles, Skills and Training Programs in the Factory of the Future. *22nd IEEE International Conference on Industrial Technology (ICIT)*, pp. 1240-1245.
- PORTUGAL, I., ALENCAR, P. & COWAN, D. 2018. The use of machine learning algorithms in recommender systems: A systematic review. *Expert Systems with Applications*, 97, 205-227.
- POULSEN, S. & IPSEN, C. 2017. In times of change: How distance managers can ensure employees' wellbeing and organizational performance. *Safety Science*, 100, 37-45.
- RAJASHEKARAPPA, M., TURANOGLU BEKAR, E., KARLSSON, A., BOKRANTZ, J. & SKOOGH, A. Bridging the Gap by Analyzing AI Deployment Challenges and Solutions in Manufacturing. CIE 52 Conference Proceedings, 2025 CIE 52, INSA Lyon, France.
- RIKALA, P., BRAUN, G., JÄRVINEN, M., STAHRÉ, J. & HÄMÄLÄINEN, R. 2024. Understanding and measuring skill gaps in Industry 4.0 — A review. *Technological Forecasting and Social Change*, 201.
- ROMERO, D. & STAHRÉ, J. 2021. Towards The Resilient Operator 5.0: The Future of Work in Smart Resilient Manufacturing Systems. *Procedia CIRP*, 104, 1089-1094.
- ROMERO, D., STAHRÉ, J. & TAISCH, M. 2020. The Operator 4.0: Towards socially sustainable factories of the future. *Computers & Industrial Engineering*, 139, 106128.
- ROTH, E., MOENCKS, M., BEITINGER, G., FREIGANG, A. & BOHNÉ, T. Microlearning in Human-centric Production Systems. 2022 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 7-10 Dec. 2022 2022. 0037-0041.
- SHMATKO, N. & VOLKOVA, G. 2020. Bridging the Skill Gap in Robotics: Global and National Environment. *Sage Open*, 10, 2158244020958736.
- SMIL, V. 2021. *Grand Transitions: How the Modern World Was Made*, New York, Oxford University

- Press.
- SÖDERLUND, H., ZAMOLA, S., BOSTRÖM, J., LI, D., MUGUR, P., CAO, H. & JOHANSSON, B. The creation of a Multi-User virtual training environment for operator training in VR. In: ENGINEERING, A. I. T., ed. Swedish Production Symposium, 2024 Trollhättan.
- SOLINAS, G., FANTONI, G., ADDABBO, T. & FARERI, S. 2020. The Human Side of Digital Revolution: Text Mining Tools to Face Industry 4.0 Phenomenon.
- SØRENSEN, C. & LUNDH-SNIS, U. 2001. Innovation through Knowledge Codification. *Journal of Information Technology*, 16, 83-97.
- STAHRE, J. 1995. Evaluating human/machine interaction problems in advanced manufacturing. *Computer Integrated Manufacturing Systems*, 8, 143-150.
- STAVROPOULOS, P., FOTEINOPOULOS, P., STAVRIDIS, J. & BIKAS, H. 2023. Increasing the industrial uptake of additive manufacturing processes: A training framework. *Advances in Industrial and Manufacturing Engineering*, 6, 100110.
- SYBERFELDT, A., DANIELSSON, O., HOLM, M. & WANG, L. 2016. *Dynamic Operator Instructions Based on Augmented Reality and Rule-based Expert Systems*.
- TAN, C. 2017. Lifelong learning through the SkillsFuture movement in Singapore: challenges and prospects. *International Journal of Lifelong Education*, 36, 278-291.
- TREVISAN, A., ACERBI, F., DUKOVSKA-POPOVSKA, I., TERZI, S. & SASSANELLI, C. 2024. Skills for the twin transition in manufacturing: a Systematic Literature Review. *Journal of Cleaner Production*, 474, 143603.
- UNESCO 2021. *Reimagining our futures together: a new social contract for education*.
- UTBILDNINGSDEPARTEMENTET 2025. En STEM-strategi för Sverige. In: REGERINGSKANSLIET (ed.).
- VUORIAINEN, A., RIKALA, P., HEILALA, V., LEHESVUORI, S., OZ, S., KETTUNEN, L. & HÄMÄLÄINEN, R. 2025. The six C's of successful higher education-industry collaboration in engineering education: a systematic literature review. *European Journal of Engineering Education*, 50, 26-50.
- WORLD ECONOMIC FORUM 2019. *Towards a Reskilling Revolution - Industry-Led Action for the Future of Work. Centre for New Economy and Society Insight Report*. Geneva, Switzerland.
- WORLD ECONOMIC FORUM 2023. *Future of Jobs Report*.
- WORLD ECONOMIC FORUM 2025. *Future of Jobs Report*.
- WORLD MANUFACTURING FORUM 2019. *The 2019 World Manufacturing Forum Report - Skills for the future of manufacturing*.
- WORLD MANUFACTURING FOUNDATION 2024. *2024 World Manufacturing Report – New Perspectives for the Future of Manufacturing: Outlook 2030*.
- YEAGER, D. S. & DWECK, C. S. 2012. Mindsets that promote resilience: When students believe that personal characteristics can be developed. *Educational Psychologist*, 47, 302-314.
- ZHENG, J. & SHI, Q. 2022. An Empirical Study on Cross-Border E-Commerce Talent Cultivation Based on Skill Gap Theory and Big Data Analysis. *Journal of Global Information Management (JGIM)*, 30, 1-32.

