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How Siemens Empowered Workforce Re- and Upskilling Through Digital Learning

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How Siemens Empowered Workforce Re- and Upskilling Through Digital Learning

The accelerating digital transformation of manufacturing is enhancing automation and production efficiency while requiring employees to develop new skills to meet evolving demands. This case study examines how Siemens embedded a human-centric, bottom-up approach to empower employee re- and upskilling through innovative digital learning. Aligned with Siemens's actions, we present a four-phase model on leveraging information systems to address skill gaps, enhance adaptability and tackle re- and upskilling challenges. We also provide five recommendations to help organizations foster lifelong learning in dynamic manufacturing environments.[1,2]

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Re- and Upskilling in the Era of Digital Transformation

Digital transformation in manufacturing is reshaping the global workforce, requiring employees to develop entirely new skills or face obsolescence. In Europe alone, 77% of companies report skills shortages. Existing workers often need more qualifications to thrive in a digitized workplace as well.[3] In manufacturing, the fourth industrial revolution (I4.0) is accelerating this shift through technologies—such as the industrial Internet of Things (IoT), cyber-physical systems and generative artificial intelligence (AI)—which enhance production

1 Jan vom Brocke is the accepting senior editor for this article.
2 We thank Siemens for their outstanding collaboration during our project and the creation of this article.
3 The European Union announced 2023 as the "European Year of Skills" and dedicated resources to this goal. See *European Year of Skills 2023*, European Commission, December 2022, available at https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-year-skills-2023_en

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Table 1: Organizational Challenges for Implementing Digital Re- and Upskilling

Organizational Level	Core Questions (all stakeholders except AI developers, please respond)
Strategic	Anticipating skill changes driven by rapidly evolving technologies like AI and IoT in order to prepare the workforce for digital transformation.
	Continuously developing and updating re- and upskilling programs to address critical skill shortages.
	Balancing the short-term cost-efficiency of standardized, one-size-fits-all training with the effectiveness of personalized learning in order to achieve optimal workforce outcomes.
Strategic	Equipping managers with tools to assess employees' skills and create targeted training plans that support organizational needs and individual career aspirations.
	Using real-time data to make re- and upskilling programs adaptive to shifting business priorities.
	Bridging the gap between corporate e-learning programs and employees' perceived value of those programs.
Strategic	Effectively managing large teams while addressing the specific needs of individual employees.
	Resolving logistical challenges by addressing when, where and how employees can participate in training without disrupting workflows or exceeding resource limitations.

efficiency and quality. At the same time, digital transformations also depend on people and processes, which account for 70%, on average, of whether a transformation succeeds or fails, according to estimates by the Boston Consulting Group, while the effectiveness of algorithms and other technologies contributes the remaining 30%.[4]

In response, organizations must proactively prepare employees to navigate today's rapid technological advances and build a future-ready workforce capable of sustaining productivity and innovation. This challenge, however, presents a critical question for executives: How can organizations build a future-ready workforce that embraces digital transformation and rapidly adapts to change while also sustaining productivity and innovation?

Although the need for re- and upskilling is evident, implementing effective re- and upskilling programs presents considerable hurdles across all organizational levels.

These challenges can be grouped into three key areas (Table 1). The *strategic level* focuses on aligning future skill needs and market trends with workforce development and long-term organizational goals to remain competitive. At the *tactical level*, practical tools are needed to assess skill gaps, align training with employee aspirations and adapt initiatives to shifting business needs. The *operational level* addresses the practicalities of how, when and where employees can acquire skills, ensuring training delivery is efficient, accessible and relevant.

Organizations have two primary options for addressing workforce development challenges: 1) expanding human capital-intensive in-person training, and 2) leveraging information systems for digital re- and upskilling. Unfortunately, traditional in-person training models often lack scalability, efficiency and adaptability to rapidly changing skill demands, making it challenging to address workforce development needs effectively at scale.[5] In contrast, integrating digital solutions with human-centric approaches could potentially overcome these barriers, empower employees and foster sustained growth and resilience.

4 The Boston Consulting Group, for example, notes that upskilling is essential to include in organizational practices, especially around the use of AI. See Loh, H. et al. *Five Must-Haves for Effective AI Upskilling*, BCG, available at https://www.bcg.com/publications/2024/five-must-haves-for-ai-upskilling.

5 See Hall, S. et al. *The Skills Revolution and the Future of Learning and Earning*, McKinsey & Company, 2023, pp. 1-49.

Information systems can thus play a critical role in re- and upskilling by delivering personalized learning experiences tailored to individual needs.[6] Online platforms—like Coursera, Open edX and LinkedIn Learning—use data, such as course engagement metrics and skill assessments, to create targeted, job-specific training. In manufacturing, these solutions address diverse skill requirements by offering scalable, flexible training that adapts to technological advances like AI and IoT. Digital re- and upskilling also allows employees to minimize production downtime while enhancing their workflows, helping workers excel in evolving roles. Additionally, digital learning reduces costs and offers flexibility, allowing employees to learn at their own pace and location. These benefits improve knowledge retention, job satisfaction and professional growth, making digital learning a cornerstone of workforce development in manufacturing and beyond.

To maximize the effectiveness of these initiatives, organizations are increasingly adopting a human-centric approach to workforce development, thereby addressing the growing need for personalization. By moving away from one-size-fits-all training programs, this approach prioritizes employees' unique needs and aspirations while aligning skill development with organizational objectives. By leveraging data-driven diagnostics, organizations can identify individual strengths and tailor learning paths to foster employee empowerment and career progression.

This article presents a case study of Siemens Digital Industries that offers practical, tested strategies that combine a human-centered, workforce-development approach with information systems. The case study analyzes employee and managerial requirements and organizational considerations that shaped the solution that Siemens developed for effective human-centric re- and upskilling initiatives in the manufacturing sector.[7]

The Value of Human-Centricity in Highly Automated Work Environments

As companies increasingly adopt AI, employees often face uncertainty about their future roles, career paths and the skills required to thrive in increasingly automated environments. Striking a balance between automation and human labor is thus essential to preserving employment opportunities while leveraging human adaptability and problem-solving skills in areas where technology alone falls short.[8]

In the journey toward digitalization, experience shows that placing employees at the heart of strategic considerations is critical to fostering engagement and performance.[9] This is especially important given ongoing demographic shifts and talent shortages, which heighten the need to create roles that are both valuable to the organization and attractive to individuals. Skilled workers, after all, are more likely to stay or accept roles when provided with long-term incentives, access to advanced technology and opportunities to participate in decision-making processes and grow their careers.

This is where the human-centric perspective comes into play. As articulated by the World Economic Forum and others, "human-centricity," also referred to as people- or employee-centricity, emphasizes principles such as self-determination, autonomy and empowerment. In highly automated environments like manufacturing, this can translate into designing processes and technologies that actively enhance employees' interactions with machines, such as intuitive user interfaces or accessible training for new technologies.

This approach redefines traditional top-down management practices by prioritizing employees' needs while placing them at the heart of decision-making processes and fostering alignment between individual and organizational goals. In contrast to the technology focus of I4.0, human-centricity emphasizes enhancing

6 Ritz, E. et al. *What to Learn Next? Designing Personalized Learning Paths for Re-&Upskilling in Organizations*, Proceedings of the 56th Hawaii International Conference on System Sciences, 2024.

7 Please see the Appendix for a detailed explanation of our methodology.

8 See Kong, X.T.R. et al. "Industrial Wearable System: The Human-Centric Empowering Technology in Industry 4.0," *Journal of Intelligent Manufacturing* (30:8), 2019, pp. 2853-2869.

9 See *Industry 5.0: Towards a Sustainable, Human-Centric and Resilient European Industry*, European Commission, January 2021, available at https://op.europa.eu/en/publication-detail/-/publication/468a892a-5097-11eb-b59f-01aa75ed71a1/.

individual skills and improving human-robot interaction in complex industrial systems. As such, organizations are encouraged to use technology to tailor processes to employees' re- and upskilling needs, ensuring efficiency and employee development.

The Growing Potential of Human-Centricity for Digital Re- and Upskilling

Continuous individual and organizational learning is essential in an increasingly complex environment. Digital re- and upskilling platforms meet this need by providing employees with flexible, on-demand access to knowledge and skills.[10] These platforms include e-learning courses, training sessions, virtual-reality simulations and online materials delivery. By utilizing AI and analytics, such platforms provide personalized course suggestions, customized content and instant feedback to foster employee growth.

Although these platforms address employee re- and upskilling needs, their effectiveness and usability are often questioned. Indeed, many employees perceive corporate digital learning programs as ineffective; in one survey, for example, only 44% of respondents expressed satisfaction with such platforms.[11] This reality highlights the importance of bridging the gap between program implementation and perceived value.

One primary reason might be the *self-regulation* that employees require to successfully complete their courses, such as integrating online learning into their work schedule and prioritizing it. Contrary to the assumption that adult learners should be relatively self-directed in learning, in reality, they often need professional help and social support to fulfill their re- and upskilling ambitions. Human-centricity—through personalized feedback, interactive content and direct-support mechanisms—has the potential to address these gaps and enhance employee engagement. This potential is also growing with AI's numerous opportunities for personalization and targeted learning guidance.

Employee *attitudes* toward re- and upskilling influence learning behaviors and intentions, too. As more re- and upskilling programs move online, the growing importance of human-centricity lies in nurturing learners, ensuring professional guidance and fostering social interaction to increase satisfaction and learning completion rates. The support and design of instruction determine the effectiveness of digital learning as well.[12] By taking these factors into account, employee education can serve as a sphere of and a spur for empowerment in the workplace. That's why digital re- and upskilling courses should be designed to enable learners to gain control over their careers and develop new skills.[13]

Below, we describe in detail the activities that Siemens undertook to introduce a human-centered approach to digital re- and upskilling at their manufacturing sites.[14] At a high level, two priorities stand out. First, with Siemens's company-wide slogan "Making learning a habit," they strongly emphasized learning as a strategic asset for the future. Further, in 2022, Siemens invested €280 million in training and education.[15] This investment reflects the organization's recognition of human-centricity as a core driver for building a future-ready workforce.

Second, Siemens dedicated significant resources to enhancing its highly automated and complex production processes by adapting them to human-centric principles. A critical cornerstone involved establishing an internal learning platform with more than 130,000 employee courses. The platform contributed to a 22% improvement in learning effectiveness, on

10 See Gupta, S. and Bostrom, R. P. "Technology-Mediated Learning: A Comprehensive Theoretical Model," *Journal of the Association for Information Systems* (10), 2009, pp.686-714.

11 *Why People Are Quitting Their Jobs, Statista*, April 2022, available at https://www.statista.com/chart/27830/reasons-for-quitting-previous-job/.

12 Bell, B. S. et al. "100 Years of Training and Development Research: What We Know and Where We Should Go," *Journal of Applied Psychology* (102:3), 2017, pp. 305-323.

13 See Boyadjieva, P. and Ilieva-Trichkova, P. "Adult Education as a Pathway to Empowerment: Challenges and Possibilities," in Holford, J., Boyadjieva, P., Clancy, S., Hefler, G. and Studená, I. (eds.) *Lifelong Learning, Young Adults and the Challenges of Disadvantage in Europe*, Palgrave Macmillan, 2023, pp. 169-191.

14 This structure syncs with that described by Ludwig and van Giffen. See Van Giffen, B. and Ludwig, H. "How Siemens Democratized Artificial Intelligence," *MIS Quarterly Executive* (22:1), 2023.

15 Siemens's investments in re- and upskilling have been reported in various technical research publications and in the general media.

average, while keeping user satisfaction levels high.[16]

A Brief Description of Siemens

Founded in 1847, Siemens is a German multinational company that covers the electrical, software and automation industries and forms a conglomerate with Siemens AG, Siemens Healthineers and Siemens Energy. Siemens AG employs over 300,000 people at 125 locations worldwide. Of these employees, this case study focuses on workers at Siemens Digital Industries, which specializes in producing automation equipment in smart factories. All of these facilities are equipped with the newest machinery, with more than 90% of processes fully automated.

Due to such high automation rates, Siemens had to take a bottom-up view to support employees dealing with increasingly complex machinery. Human-centricity thus offered an opportunity to create a working environment characterized by high employee participation and empowerment.

Siemens's Journey to Human-Centric Re- and Upskilling

Prior to the project phases described in this article, a Siemens internal group embarked in 2022 to develop a human-centric strategy for re- and upskilling. In the beginning, they focused on the definition of human-centricity by asking various questions. What does human-centric mean for us at this site? What are practical approaches to human-centric production? What crucial steps do we need to take for the future? How does a human-centric mindset change our decision-making processes?

Based on our interviews with two managers at Siemens who were responsible for initiating human-centricity, the company's core ambition can be described in the following way:

> *"When we look at the processes or production, we [now] focus on the people who ultimately work for us. We have always been very process-driven from the whole line background. We previously focused on what happens to the workpiece and rarely looked in detail at what it is like for the people who carry it out."* Human-Centricity Expert 1.

Based on these initial efforts, Siemens's derivation of a human-centric digital re- and upskilling strategy evolved through four phases, as described below.

The following section illustrates the Siemens case study as a four-phase model (Figure 1) focused on developing a human-centric perspective for advancing digital re- and upskilling. The project was conducted from August 2022 to August 2023 by a project team, including the authors of this article and Siemens employees. In Phase 1, the team analyzed what employees need for successful digital learning. In Phase 2, the team identified the employee personality traits that shape the impact of digital tools for successful learning experiences. In Phase 3, previous insights about employees and their traits were used to develop human-centric digital re- and upskilling strategies, emphasizing a tailored approach to digital education. And in Phase 4, these strategies underwent strategic validation and were fine-tuned to align with Siemens's organizational perspective and objectives.

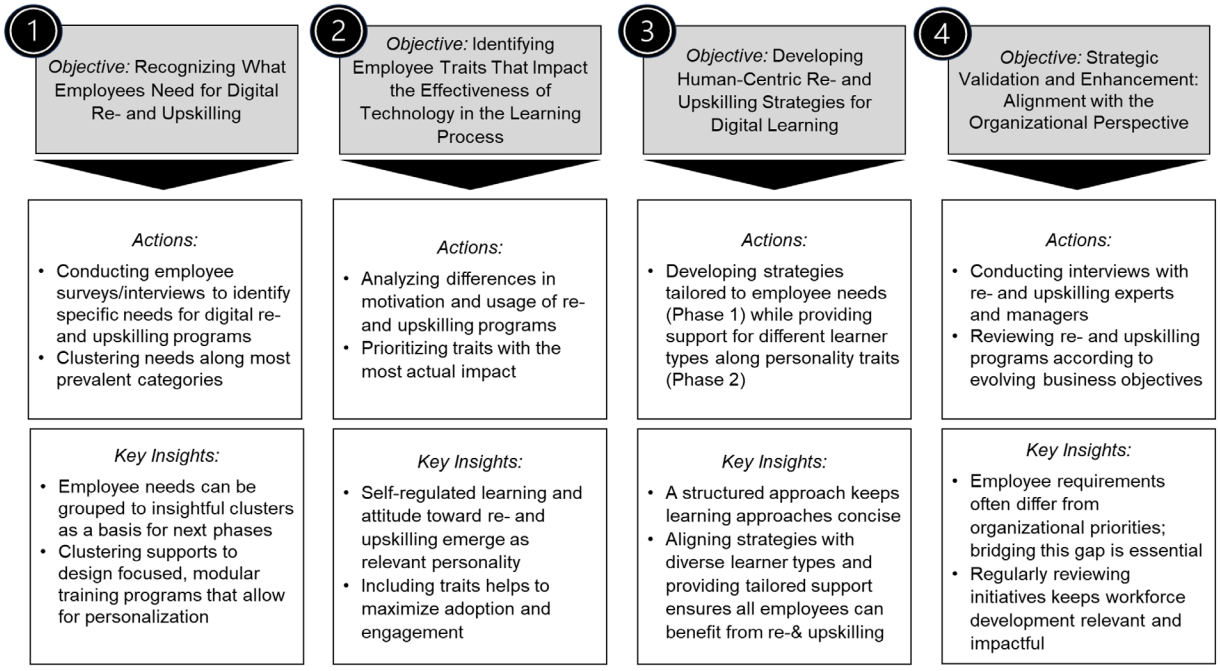
Phase 1: Recognizing What Employees Need for Digital Re- and Upskilling

Interviews with Siemens employees from diverse backgrounds were used to capture essential requirements for a human-centric digital re- and upskilling strategy. These interviews focused on the needs that employees identified as crucial for their empowerment. The interviews included six requirement categories (A-F).

A: Development of task-oriented re- and upskilling courses. Siemens employees require task-oriented training that matches their skills and job profiles. This training requires both interdisciplinary courses targeted at a broad range of employees with different backgrounds (such as digitalization awareness training) and specialist training courses targeted at one specific job profile (such as software/ hardware training). As one interviewee noted:

16 See Brehm, R. *CEO Factory Automation at Siemens Digital Industries*, Siemens, June 2022, available at https://blog.siemens.com/2024/05/why-the-future-of-industrial-production-requires-a-people-centric-approach/.

Figure 1: Four-Phase Model for Developing Human-Centric Re- and Upskilling



> *"Let's take this Lean Expert course as an example. Sure, the methods are open. But if you have five reorganization planners, two quality experts and two logistics experts participating, the course will primarily deal with production-related topics in one week. Then there is a high risk that the other four participants will only learn half of it, because you have to apply the method targeted for your job and then, in the course, you will take examples from the planners. You can't do justice to everyone."* Participant (P) 13, works in logistics planning

B: Provide exchanges with coaches, mentors and peers. Employees desire exchanges with coaches and mentors to discuss lessons learned and the implementation/translation of the acquired knowledge into their everyday tasks. Moreover, the exchange between peers from different backgrounds during and after training is widely perceived as very beneficial. Another interviewee told us: "I think it's good to get together with other people whom you haven't been in contact with before. That was good that you also learn something from others" (P23, electrician).

C: Increase knowledge retention and on-the-job training. Managing knowledge retention is vital for both organizations and employees in order to ensure the effectiveness of acquired knowledge. Interviewees also highlighted the importance of on-the-job training and learning, especially hard-skill training for new production machines: "I think I've probably heard 80% of the information already. The problem is always regular repetition—perhaps also connections between some techniques or simply applying them" (P13, logistics planning).

D: Provide timely and regular feedback. Another requirement was the timely availability of feedback after a course or learning session from direct managers and/or the re- and upskilling platforms themselves. This feedback includes information like "objective learning success measurements" that detect skill gaps. One interviewee noted:

> *"That [timely and regular feedback] has already helped me a lot. The fact that you always have feedback on 'how did you do*

that?' And that [feedback] must always take place. ... Because if you don't get any, then you don't know where you stand. But when people tell you that you might have deficits or that you can improve, that's very important." P1, system administrator

E: Provide learning paths. Simplifying employees' search process for suitable training allows for quicker course selection, which can also decrease dropout rates. For instance, employees often do not complete courses because they don't offer the right difficulty level or content. This problem could be solved through either a manager's personalized course recommendations or a learning system based on learners' interests, skill profiles and career objectives. An interviewee said: "I think the most valuable thing would still be that we have content that really fits the task requirement. ... And that I can also set a certain direction for my learning. When I can say, 'I will take this journey and I divide it up myself.' But the content, then, is connected" (P21, project manager).

F: Expand the use of learning nuggets. At Siemens, micro-learnings—"learning nuggets"—are increasingly developed and used for small-scale training. These have proved to be powerful learning tools, especially among shopfloor employees, who can use such training during, say, a short production stop. Similarly, the provision and extension of learning nuggets was emphasized by our interviewees as an essential requirement.

"These learning nuggets are simply short pieces of content that may only last two minutes but can convey a very nice insight for half an hour. This can also happen every morning. When I turn on my computer, I am presented with a one-minute video with some valuable content. What I get is a tip about the tools I use, which are often very simple things like tips in Outlook, PowerPoint and Excel. ... And I can certainly do this kind of learning content in the morning." P19, production planner

Phase 2: Identifying Employee Traits That Impact the Effectiveness of Technology in the Re- and Upskilling Process

Here, the interviews provided insights into significant differences in motivation and how employees use digital re- and upskilling programs. The interviews showed that personal traits significantly influence how technology should be designed and implemented. Two employee personality traits emerged as decisive: the ability to learn in a self-regulated manner and attitudes toward re- and upskilling. This finding underscores the necessity of technology to adapt to diverse user needs and its capacity to accommodate individual learning attitudes. The important role of personal traits in successfully deploying and accepting technology should thus encourage practitioners to prioritize human-centricity in their personnel development strategies.

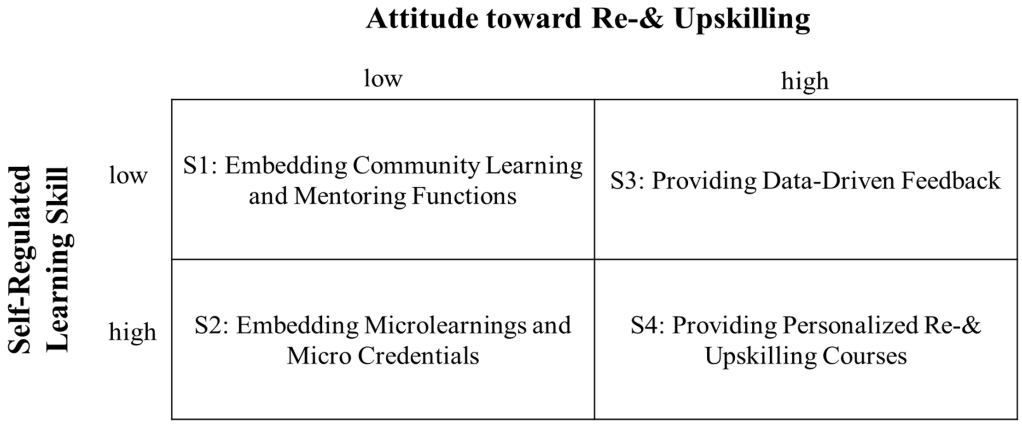
Our research further confirms that self-regulated learning is a linchpin to accomplish continuous professional development.[17] Self-regulated learning involves having the learner take charge of the learning journey, setting clear goals and selecting the most effective strategies. This skill becomes especially important in the context of digital re- and upskilling: As organizations rely increasingly on digital re- and upskilling programs, employees must become active learners. The upshot is that the ability to manage one's own learning process can make the difference between success and dropping out.

However, the journey to skill proficiency is not solely about self-regulated learning. It is also about attitudes toward learning activities; after all, attitude is pivotal in determining outcomes, especially in digital learning environments. In this context, "attitude" is a relatively stable disposition that explains a person's reactions to objects or events, including learning.[18] We also found that employees' attitudes toward various aspects of learning significantly influence workers' ongoing commitment to digital learning. Notably, we found a substantial improvement in employees' favorable attitudes toward online learning after engaging in training—thereby boosting workers'

17 See Zimmerman, B. J. "Becoming a Self-Regulated Learner: An Overview," *Theory into Practice* (41:2), 2002, pp 64-70.

18 Triandis, H. C. *Attitude and Attitude Change*, Wiley Foundations of Social Psychology Series, Wiley, 1971.

Figure 2: Human-Centric Re- and Upskilling Strategies, Depending on Both Attitude for Re- and Upskilling and Skill at Self-Regulated Learning



confidence in technology use, course satisfaction and overall enthusiasm for online learning.

Our research shows that in the digital age, strong self-regulated learning skills and a positive attitude are important determinants of successful re- and upskilling. Empowering the workforce with the right skills and mindset is therefore key to both thriving in digital environments and fostering lifelong learning—a journey that executives and managers alike should eagerly support for their employees.

Phase 3: Developing Human-Centric Re- and Upskilling Strategies for Digital Learning

Grounded in the re- and upskilling needs and the personality traits highlighted by employee interviews in the previous phases, the project team concentrated on leveraging information systems to support these employees and fulfill their requirements. Subsequently, the project team developed strategies to address their needs within a digital re- and upskilling framework. To do this, the requirements from Phase 1 were analyzed and transferred into specific organizational strategies. (These four strategies are positioned along the two personality traits from Phase 2 and are shown in Figure 2.)

The strategies aim to guide executives and practitioners in an organization-wide setting. However, the strategies are not mutually exclusive and are anticipated to be most effective within their respective classifications. Nevertheless, their implementation should remain distinct from any assessment: The aim is not to alter the strategies, but to respond appropriately to varying circumstances. (The four organizational strategies [S] for implementing re- and upskilling are also displayed in Figure 2, according to the clustering alongside the employee personality traits.)

Phase 4: Strategic Evaluation with Learning Experts—Alignment with the Organizational Perspective of Siemens

Strategy 1: Embedding Community and Mentoring Functions (Requirement B). Embedding community learning and mentoring functions suits employees with low (i.e., weak) self-regulated learning skills and low attitudes toward re- and upskilling. Encouraging social exchange, however, can help address these challenges. Community functions—like real-time chat and group spaces for ongoing collaboration—facilitate interactive spaces for learners to engage in discussions, work on projects together and share insights, thereby cultivating a solid learning culture. Further, social exchange can enhance the enjoyment factor of learning and, in turn, lower barriers to engaging in re- and upskilling. Similarly, mentoring

functions provide learners with direct access to experts or more experienced peers for guidance, feedback and support.[19] These functions foster a supportive learning environment, promoting learning through collaborative problem-solving and empowerment by mitigating the isolation frequently encountered in digital learning contexts.[20] Addressing the cognitive and social aspects of learning and incorporating community and mentoring functions creates a more holistic and effective learning experience.

Strategy 2: Expanding micro-learnings, increasing on-the-job training (Requirement C + F). Embedding micro-learnings and micro-credentials is particularly valuable for employees with high (i.e., strong) self-regulated learning skills yet low attitudes toward re- and upskilling. Although their ability to set goals for short learning pieces is high, such workers need a step-by-step perspective on why learning is necessary.

Micro-learning, as noted, refers to decomposing extensive learning material into small, comprehensive nuggets. Evidence shows that micro-learning leads to better learning engagement and motivation. Our interviewees also suggested that this strategy can notably benefit employees who struggle with self-regulated learning and have a negative attitude toward re- and upskilling. These employees can set short-term goals, such as watching a five-minute video, allowing them to stay engaged without requiring extended focus.

Micro-credentials can enrich this format as well. Such credentials—small qualifications, like digital badges and awards, that demonstrate an employee's knowledge or skill—mainly contribute to learners' extrinsic motivation, since they can show off their credentials to peers and managers.[21]

Strategy 3: Providing timely and regular data-driven Feedback (Requirement D). Learners who have low self-regulation learning skills—but who also have a high attitude toward re- and upskilling—need accurate and, ideally, data-based feedback that provides guidance and structure alongside the learning process. Dashboards, for example, can present this information by featuring analytics on previously covered courses and topics and performance comparisons with peers.

Research also shows that learners often struggle with self-regulation during online learning, where they are required to monitor their progress toward completion of a course.[22] When direct feedback from managers to guide learners toward re- and upskilling activities is unavailable—due to factors like insufficient time on the part of managers—technology can provide practical advice to learners based on learning data. In that vein, employees do not solely need to rely on managers' feedback but can get immediate, data-driven feedback through a new medium. When this happens, employees tend to feel more empowered because they better understand both their progress and areas that need improvement. A data-driven approach can thus help provide timely feedback that can be used to adjust training programs accordingly.

Strategy 4: Provide personalized re- and upskilling courses (Requirement A + E). When employees have high self-regulatory skills and high attitudes toward re- and upskilling, they are well-positioned to set their own re- and upskilling goals and structure their learning process. As a result, focusing on motivating and otherwise helping such employees during learning will have a lower impact than on them than on other types of workers. Instead, it is vital to provide support beforehand with personalized recommendations for re- and upskilling that fit the former group of employees' educational and expertise level, current position and personal interests so that they do not get overwhelmed in the course-search process. In the past, the course recommendation was under the direct manager's responsibility as part of career development. Today, digital learning systems are paving the way instead for personalized re- and upskilling courses that foster employee empowerment for improved learning outcomes.

19 Notably, female mentees may derive greater network benefits from formal mentoring due to these legitimacy-enhancing signals. See Srivastava, S. C., Chandra, S., and Shirish, A. "Technostress Creators and Job Outcomes: Theorising the Moderating Influence of Personality Traits," *Information Systems Journal* (25:4), 2015, pp. 355-401.

20 Carvalho, A. R. and Santos, C. "Developing Peer Mentors' Collaborative and Metacognitive Skills with a Technology-Enhanced Peer Learning Program," *Computers and Education Open* (3), 2022, Article 100070.

21 The CEDEFOP provides information for re- and upskilling with actual data and country-specific insights from the EU.

22 Kizilcec, R. F., Pérez-Sanagustín, M., and Maldonado, J. J. "Self-Regulated Learning Strategies Predict Learner Behavior and Goal Attainment in Massive Open Online Courses," *Computers & Education* (104), 2017, pp. 18-33.

To evaluate the credibility of the re- and upskilling strategies that we synthesized, the project team also discussed our research results with two groups of experts at Siemens—learning managers and managers with extensive knowledge of workforce development. This phase aimed to incorporate the resulting insights into the four strategies described above (S1–S4) while assessing their practicality and implementation recommendations. Additionally, the project team asked the aforementioned experts if they believe that Siemens's human-centric perspective is aligned with the above strategies.

These experts' responses confirmed the importance of aligning digital re- and upskilling strategies with the personality traits of 1) self-regulated learning skills and 2) personal attitudes toward re- and upskilling. A critical insight from the discussions was the validation of self-directed learning and the development of a positive attitude toward learning as central to human-centricity: "For me, the two parameters are already an expression of human-centricity" (Learning Expert 1).

The experts we interviewed consistently emphasized how the joy of learning improves learning outcomes and highlighted the importance of exploring various channels to enhance retention. While the need for self-directed learning appears to be universal among white- and blue-collar employees alike, its application and experience might differ among individuals. This finding underscores the necessity of a flexible, personalized approach to learning that considers personal interests, motivation and the unique ways that individuals engage with and process new information. "I also think that personal interest in the work or personal motivation must, of course, be taken into account" (Learning Expert 1). "I think that the white-collar workers have exactly the same topic, but perhaps experience motivation or this self-directed learning differently and also live it differently" (Learning Expert 2).

These interviews also revealed insightful perspectives on how to refine learning strategies within a high-demand manufacturing environment like Siemens Digital Industries. For example, one interviewee (Learning Expert 1) emphasized the effectiveness of micro-learning as a strategic approach that is well-tailored to the realities of the workplace, where time is a precious commodity. This approach—characterized by brief, concentrated learning sessions—was widely acknowledged by interviewees as a valuable method for integrating learning into the bustling rhythm of the workday.

Additionally, the idea of fostering a supportive learning ecosystem was brought up (Learning Expert 2), suggesting the importance of integrating platforms for mentorship and peer learning: "What would help me is to have an accompanying platform, such as a mentor, but also learning partners—so peers who have a similar or the same goal and the learners then make appointments with each other and go into exchange with each other." In line with this strategy, Siemens's approach to establishing a contact person (a "learning coach") was discussed: "I believe that when it comes to all this technological learning, especially on the shop floor, you have to carefully guide the learners. … I'm always a fan of mentoring or contact persons, something accompanying, where you can simply turn to with questions, especially if you have learning opportunities to fulfill by yourself" (Learning Expert 3).

These interviews, in short, validated our findings (as summarized in Figure 2) while further highlighting the importance of aligning personality traits and strategies with Siemens's human-centric organizational perspective. In other words, aligning a bottom-up approach—where employees are the starting point of consideration—with an organization's goals should be a priority.

Through our research, we also deepened our understanding of practical applications within Siemens. For example, at the end of the four phases, Siemens overcame employees' skepticism about digital approaches for both production and personal training/development. Instead of starting with a predetermined technical solution and then looking for a suitable use case, employees were involved in identifying the areas where they needed support. Next, solutions were developed together, involving different levels of the organization.

The results were strikingly positive. Indeed, many employees were amazed that their needs were recognized at all. Such reactions spurred positive learning outcomes.

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Table 2: Recommendations for Supporting a Human-Centered Digital Re- and Upskilling Approach

Recommendation	Recommended Actions	Exemplary Siemens Solution	Business Val-ue
R1: Foster a lifelong-learning culture in the or-ganization	Integrate learning objectives into organizational values and performance reviews. Recognize and reward continuous learning efforts.	Increase accessibility to digital learning tools.	Agile response to changing skill demands.
R2: Tailor digital learning programs to individual needs and outcomes	Develop adaptive learning systems that adjust content based on employee preferences and performance. Include role-specific, outcome-driven training.	Digital re- and upskilling platforms with role-specific learning paths.	Cost-efficient learning; employee satisfaction.
R3: Develop a dedicated space for collaborative learning and mentorship opportunities	Implement platforms that encourage peer-to-peer learning and mentorship. Facilitate the sharing of best practices and knowledge across teams.	Digital learning coaches.	Efficient knowledge management; employee satisfaction.
R4: Incorporate flexible training formats for diversified and adaptable learning schedules	Embed learning moments into daily activities. Design micro-learning modules that align with employees' roles and tasks.	Digital learning hours; physical space for online training in manufacturing; micro-learnings.	Workflow optimization; process efficiency
R5: Use people analytics to provide feedback	Leverage analytics to identify skill gaps and training impact. Provide personalized feedback and track progress against predefined goals.	Progress-monitoring on learning platforms; growth talks.	Improved performance; employee satisfaction

"It is also important for the long-term formation with regard to demographic change that the jobs remain attractive and that people enjoy working for us. […] It is not just service by the book but because you have a voice" (Human-centricity Expert 1).

Recommendations for Designing Human-Centric Digital Re- and Upskilling Solutions

Drawing on the above research, we present four strategies for effective digital re- and upskilling. These strategies represent four ways in which technology can better serve the personalization of learning content that is adapted to the individual levels of two traits (self-regulated learning and attitudes toward learning). Based on these strategies, we derived five recommendations (R1-R5) for executives and managers who aim to implement digital learning in a human-centric way.

Our recommendations were developed in collaboration with Siemens and are summarized in Table 2. To increase the impact of these recommendations, we included corresponding actions on how to best implement the recommendations. Table 2 also displays an "exemplary learning" measure that Siemens integrated after following these recommendations and the resulting business value that was created.

R1: Foster a Lifelong Learning Culture in the Organization

At the heart of a human-centric organization lies a lifelong learning culture. Achieving such cultural change requires not only significant

time but also employees' own effort, motivation and resilience to adopt this mindset. In this case study, Siemens dedicated significant resources to learning—in terms of both monetary and personnel investments—and heavily transformed their corporate culture according to their slogan: "Making learning a habit." This included a strong commitment to the mission from C-level executives and managers across the organization. These efforts also systematically lowered barriers for employees to access re- and upskilling offerings. Further, Siemens actively ensured the accessibility of their digital re- and upskilling tools for everyone, especially employees from manufacturing. Today, every employee in a Siemens factory is equipped with a digital ID, including an email address, and can access all the company's online platforms, including its intranet.

With today's ongoing technological advances, a lifelong learning culture can help the organization stay agile and competitive. And by actively anchoring a lifelong learning mindset in their organizational cultures, other organizations can better react to their own strategic challenges, too.

Meanwhile, employees who are eager to learn can engage in new skill areas and technologies early on, facilitating the detection of potential future-relevant skills or job profiles. In such an environment, continuous learning can be supported by employees who actively feed the re- and upskilling program with their knowledge of the organization's processes and acquired knowledge—thereby contributing to organization-wide knowledge transfer and an up-to-date database that can tackle the skill shortages of other employees.

R2: Tailor Digital Learning Programs to Individual Needs and Outcomes

Personalizing re- and upskilling courses represents a significant step toward addressing employees' varied job needs and learning paces. This recommendation also serves as another way to ensure that human-centricity is prioritized in all learning activities. For their part, executives and managers should support the development of adaptive learning paths that tailor the complexity and learning style to the employee's preferences and competencies.

Siemens, for example, developed digital learning platforms that offer functionalities to integrate learnings for specific groups or job roles so that employees get personalized course recommendations when visiting the platform. At Siemens, it is also possible to filter courses according to one's job role or skills and to pursue different learning paths on the platform.

For all organizations, personalized re- and upskilling can contribute to overcoming the challenge of balancing training costs with effectiveness. Generic one-size-fits-all programs tend to waste resources and time, since only part of the information is often relevant to employees. Instead, personalized learning paths offer a more efficient and cost-effective long-term solution because they optimize learning time with relevant training that directly contributes to employee development, thereby enhancing human capital. Moreover, personalized learning paths provide employees with tailored, dynamic content that aligns with their job roles, learning styles and individual preferences. This approach enables barrier-free access to training while facilitating an inclusive re- and upskilling environment. Employees benefit from increased satisfaction as well, since their courses are directly relevant to their careers and personal growth.

R3: Develop a Dedicated Space for Collaborative Learning and Mentorship Opportunities

Mentoring networks play a significant role in enhancing employees' professional development and career success. To include a specific function for peer exchange and mentoring in learning programs, it is necessary to evaluate current programs and available options to integrate community-learning features, both digital and non-digital. Digitally, customization with features like forums, chat functionalities and video conferencing tools ensures the platform meets the specific needs of learners and mentors. Non-digitally, by establishing discussion forums and project collaboration areas, learners are provided with venues to engage in meaningful conversations, tackle challenges collectively and share resources.

Siemens, for instance, started here with "digi-coaches"—mentors for the learning platform's technical use. These pretrained employees

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serve as mentors, offering guidance, sharing experiences and fostering a sense of community among learners. Their presence contributes to a supportive, collaborative, learning environment within the organization and has been very well received by employees.

Organizations can thus balance the tactical challenge of both managing large teams and providing individual support by establishing a digital re- and upskilling platform with functionalities for collaborative learning and mentorship. By promoting mentorship, employees can share their knowledge with peers and, accordingly, react to individual needs outside managers' scope and schedules. And through collaboration with other managers, the assessment of skills and the implementation of a development plan can be shared and, in turn, improved.

For employees, access to managers and job-related mentoring sessions has many advantages. For example, integrating mentorship programs involves the creation of mentor profiles and a matching system to pair learners with mentors, based on shared goals and interests. Incorporating scheduling tools for mentorship sessions and enabling real-time communication through live chat and video calls can also foster immediate feedback and personal interactions. And implementing collaborative tools—such as a shared resource repository and peer-review mechanisms—cultivates a culture of continuous feedback and improvement, which is essential for fostering a supportive, dynamic, learning community. Ultimately, effective mentoring produces enhanced skills and legitimacy-enhancing signals.

R4: Incorporate Flexible Training Formats for Diversified and Adaptable Learning Schedules

Incorporating flexible training formats, such as micro-learning, is essential for creating an adaptable, diversified, learning schedule. Breaking down complex training into short, focused modules allows employees to integrate learning into their daily routines without feeling overwhelmed. To succeed, organizations must therefore clearly define the skill and knowledge areas that need to be addressed, align learning goals with organizational objectives and design content that fits into daily workflows. Guidelines for learning are also necessary to ensure alignment with personal and organizational needs.

For its part, Siemens embraced micro-learning as part of its human-centric re- and upskilling strategy, particularly in manufacturing.[23] For instance, Siemens created QR codes linking to small-sized tutorials for their machinery, enabling employees to access targeted learning resources at any time. These micro-learnings fit seamlessly into employees' workflows while addressing relevant skill areas, such as understanding the function of a robot through short videos.

Siemens also set guidelines for learning in the organization by providing a defined number of hours that employees are paid to learn; Siemens has increased its target to 25 annual digital learning hours per employee by the end of 2025. In addition, a designated office room with PC equipment was established for all manufacturing employees to enable them to achieve their digital learning goals at work.

Such micro-learning facilitates the creation of a learning ecosystem that is integrated with knowledge-management applications. This approach helps recognize and certify skills and achievements beyond traditional degrees, ensuring that an organization's workforce remains agile. As noted, initiatives like digital badges can complement micro-learning efforts, offering low-cost, formal recognition of employee achievements while aligning learning programs with business needs.

Setting dedicated learning hours and providing physical learning spaces in manufacturing environments further enhances the effectiveness of training programs. These initiatives create structured opportunities for learning, reduce logistical challenges and demonstrate organizational commitment to workforce development. Additionally, incorporating micro-learning allows organizations to quickly update content, ensuring the relevance and adaptability of training programs.

Micro-learning thus provides employees with an accessible, personalized way to engage

23 Siemens's process for developing micro-learnings was supported by the University of Cambridge and further described in Roth, E. et al. *Microlearning in Human-centric Production Systems*, IEEE International Conference on Industrial Engineering and Engineering Management, 2022, pp. 37-41.

in continuous learning without disrupting daily workflows. It addresses logistical barriers—such as uncertainty about when, where or how to learn—by offering on-demand, targeted training. Setting learning hours and providing physical learning spaces in manufacturing environments also allows employees to focus on their development without the pressure of managing time independently. These dedicated opportunities foster engagement, ensure equal access to learning and empower employees to manage their learning effectively, thereby easing the path to re- and upskilling.

R5: Use of People Analytics to Provide Feedback

Organizations can further empower their workforce by providing feedback through advanced analytics. The role of learning analytics in scaling the provision of personalized feedback positively impacts learners' perceptions of feedback quality and their achievements. Specifically, integrating technology to track employee progress can translate into actionable feedback (e.g., from direct managers to learners). This feedback can involve performance indicators, skill-development reports and statistics on interest areas for in-depth insights.

Siemens included a progress and success-monitoring function for their micro-learnings in order to provide such feedback to employees. Crucial for Siemens at this point was to anonymize such data and not to store it so that no type of surveillance of individual employees would be possible.[24] Moreover, Siemens integrated "growth talks" into their organizational processes: Instead of formal performance-management processes, growth talks focus on meaningful dialogue between employees and direct managers, which are closely tied to predefined strategic objectives and analytics. This method aims to promote both organizational and individual improvement.

Integrating analytics-based feedback systems supports the alignment of employee development with organizational priorities as well. Predictive analytics can also help organizations foresee potential strategic challenges, adjust skill priorities and help managers suggest customized learning paths to better align with employee skillsets. These systems also facilitate realistic goal setting and career planning—improving the organization's ability to turn data into actionable insights.

Concluding Comments

Developing and retaining a skilled and empowered workforce is critical for organizational success in a rapidly changing manufacturing environment. Our research lays out a four-phase model and identifies its pivotal role in implementing a human-centric approach for shaping successful re- and upskilling strategies. The Siemens case study underscores the significance of adopting a human-centric approach to digital re- and upskilling strategies as a way to enhance employee empowerment.

Insights gathered from employees at Siemens Digital Industries provide valuable guidance for organizations seeking to follow Siemens's successful strategy for human-centric digital re- and upskilling. Organizations that implement the recommendations in this article can better support their employees for future challenges while fostering a culture of empowerment that benefits both the individual and organization.

Appendix: Research Method

We aimed to identify a company that had invested substantially in human-centric digital re- and upskilling. In line with methodological recommendations,[25] our selection criteria led us to Siemens. Siemens has dedicated significant resources to enhancing its learning-management infrastructure, including introducing roles like "learning manager." Siemens also implemented digital re- and upskilling platforms for their blue- and white-collar workers alike.

For our overall data collection, we applied a qualitative approach and conducted interviews with 36 participants from Siemens. At the beginning of the first project phase, we recruited 28 employees from two production sites in Germany and one in the Czech Republic; all of these employees came from Siemens Digital Industries. When selecting interview

24 Due to the Works Constitution Act, German organizations must ensure that no employee performance monitoring takes place that could put employees at a disadvantage. As such, this data may neither be used nor stored.

25 See Patton, M. Q. "Qualitative Research," in *Encyclopedia of Statistics in Behavioral Science*, Wiley Online Library, 2005.

participants, we searched for diversity across demographic factors, including age, gender, education and occupation. Our final interviewee sample consisted of 64% male and 36% female participants. The most common job positions in this sample were production roles, information technology positions, engineering jobs, quality-management roles, administrative positions and leadership roles.

Although we asked participants about their general perceptions of human-centric re- and upskilling, our interviews focused on attitudes and behaviors related to existing digital re- and upskilling measures. We also asked participants about their personal re- and upskilling behavior and their organization's current upskilling activities. The latter included questions about specific activities, their effectiveness and the digital tools utilized. Finally, we explored interviewees' re- and upskilling aspirations. In addition to these employee interviews, we interviewed two experts on human-centricity at Siemens in order to enrich our case study with their perspectives on human-centricity.

Next, for Phase 4, we interviewed six Siemens learning experts and managers in Germany and Switzerland, who were all associated with the human-centric re- and upskilling initiative at Siemens Digital Industries. These interviews aimed to evaluate our studies' initial results and enrich our perspective on digital re- and upskilling. This extra step of analysis also increased the validity of our results.

We then analyzed our interview transcripts to identify similarities, differences and overarching themes. Our analysis followed a rigorous approach,[26] which involved generalizing interview material before consolidating it into the resulting statements and insights. Three authors engaged in open, axial and selective coding following general grounded-theory analysis techniques.[27] To establish intercoder reliability, these authors individually coded an initial sample of interviews and then discussed them afterward to find consensus. The authors iteratively compared, discussed and validated codes in all following coding iterations.

To ensure that we adhered to strict ethical standards, we collaboratively developed a Siemens-specific interview guideline, with practitioners aiding in tool selection, participant outreach and contextual insights. Finally, participation in our research was voluntary and interviews were conducted anonymously with Workers' Council approval. Data security was ensured through privacy-consent forms.

26 Mayring, P. "Qualitative Content Analysis," in Flick, U., von Kardoff, E. and Steinke, I. (eds.), *A Companion to Qualitative Research*, SAGE Publications, 2004, pp. 266-269.

27 See Charmaz, K. and Belgrave, L. "Qualitative Interviewing and Grounded Theory Analysis," in Gubrium, J. F., Holstein, J. A., Marvasti, A. B., McKinney, K. D. (eds.), SAGE Handbook of Interview Research, SAGE Publications, 2012, pp. 347-365; Saldana, J. *The Coding Manual for Qualitative Researchers*, SAGE Publications, 2021; and Strauss, A. and Corbin, J. *Basics of Qualitative Research Techniques*, SAGE Publications, 1998.

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