Educational Support for SMEs Transitioning from Industry 4.0 to Industry 5.0 – insights and lessons learned from European cooperation projects

Wei Deng Solvang, Bjørn Solvang, Zoltan Forgó, Heidi Kaartinen, Hao Yu, Beibei Shu

Abstract— **The ongoing transition from Industry 4.0 to Industry 5.0 brings promising prospects for small and medium-sized enterprises (SMEs) to bolster their competitiveness and sustainability. To fully capitalize the benefits brought by this transition, SMEs need to master the upskilling of their workforce that conforms to the rhythm of technological development. Creating an educational symbiosis which supports this upskilling prompt is therefore crucial. The interdependence between research and education institutions and SMEs plays a vital role in cultivating a culture of continuous learning. This enables SMEs to effectively tackle the hurdles posed by the ongoing shift from technology-driven competition to one centered around creativity. The authors explore the European projects undertaken in recent years, emphasizing the insights that have played a pivotal role in empowering SMEs to fully leverage the potential of technological advancements within Industry 5.0. Furthermore, observations concerning the collaboration between SMEs and research and educational institutions have also been incorporated.**

I. INTRODUCTION

The ongoing transition from Industry 4.0 to Industry 5.0 marks a pivotal moment for small and medium-sized enterprises (SMEs) as it opens doors to promising opportunities for enhancing competitiveness and sustainability[1]. Embracing this paradigm shift offers SMEs a chance to thrive in an increasingly dynamic and technologically advanced business landscape. However, to fully leverage the benefits presented by this transition, SMEs must proactively equip themselves with essential capabilities[2,3].

Industry 5.0, as officially coined by European Commission, prolongs the mandatory commitment of technologies in business innovation at SMEs in Industry 4.0 by further emphasizing that the beneficiaries of technological application must be human – both inside and outside of an industrial system[4,5]. For instance, human-machine interaction, in Industry 5.0, has a changing focus on combining the strengths of human and machine instead of machine substitute human in Industry 4.0. Industry 5.0 also extends human-centricity to society-centricity which aims to address "contemporary challenges, heterogeneous needs while integrating participation of the society to increase trust and acceptance"[6]. Another essential focus, yet a challenge in Industry 5.0, is scalability. By this means technology implementation needed to extend to a broad scale across value chains and ecosystems, including SMEs[6].

The significant role of SMEs as the backbone of the European economy is widely acknowledged. With a growing emphasis on human-centric technological implementation, there is a heightened focus, at SMEs, on adopting measures that ensure the understanding and effective application of technologies for the benefit of people inside and outside of SMEs.

One crucial aspect of SMEs' success lies in their ability to upskill their workforce and foster a culture of continuous learning[7,8]. Extensive research has already highlighted the challenges SMEs face in adopting Industry 4.0 technologies and the strategies and countermeasures they employ to overcome them[9,10]. However, despite these efforts, many SMEs continue to encounter difficulties in fully embracing Industry 4.0 advancements. The introduction of Industry 5.0 further complicates this endeavor as it necessitates a human-centric approach with implementation.

Education plays a crucial role in upskilling and therefore successful technological implementation[11]. It helps to overcome resistance to technological changes by promoting awareness and understanding of the benefits technology can bring. Numerous pieces of evidence support the notion that people who are educated about technology are more likely to embrace and adopt it in their personal and professional lives[12,13]. Education also equips individuals with the necessary skills and knowledge to effectively use and implement technology[14]. It provides a foundation for understanding how technology works, which is essential for successful integration in various sectors and industries[15]. Furthermore, education fosters creativity and innovative thinking, enabling individuals to produce innovative ideas and solutions for technological challenges[16]. Such developments can pave the way for novel applications and technological advancements, subsequently creating fresh business opportunities and ventures.

Acknowledging the paramount importance of upskilling, increased SMEs place education as their foremost priority, even when confronted with resource constraints. Practical

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cases have shown that, by including research and education (R&D) institutions in traditional industrial symbiosis, it can entail a mutually beneficial collaboration between SMEs and R&D institutions[17,18]. By actively participating in this collaborative approach, SMEs can access tailored educational resources and knowledge that aligns with the transformative shifts brought about by Industry 5.0.

The rest of the paper is organized as follows. In section II, the authors provide a brief exposition of Industry 5.0 and underscores the pivotal role of education as a fundamental component in the trajectory of SMEs within this paradigm. Furthermore, the authors delve into the expectations that SMEs hold for educational initiatives. The key stakeholders and affiliates of an ecosystem aimed at ensuring a tailored education program for SMEs are detailed, along with a discussion of critical factors to consider during the design of such programs. In Section III, our ongoing and previous collaborative projects within the European context are explored. Lastly, the concluding section synthesizes the insights gleaned from these projects and advocates for the establishment of a harmonious, enduring partnership between SMEs and research and development institutions. Such a partnership, it is argued, forms a foundational requirement for the sustainable growth of SMEs in the context of Industry 5.0.

II. TECHNOLOGY-DRIVEN DIFFERENTIATION

According to classical studies, exemplified by Michael Porter[19], achieving competitiveness entails differentiating itself from others, whether it be in terms of cost, quality, product, service, or the methods of conducting business. As in all previous industrial revolutions, differentiation in Industry 5.0 has heavily relied on innovative technological advancements. However, what distinguishes Industry 5.0 is its core emphasis on addressing human needs and preferences. In essence, this signifies that all employed and integrated technologies aim to enhance human contentment.
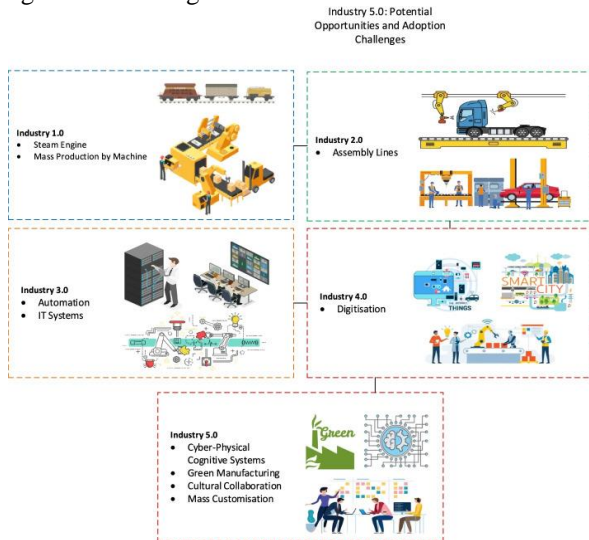

Figure 1. Industrial Evolution from Industry 1.0-5.0 [20]

In Fig 1, the evolution of industrial revolutions throughout history is depicted[20]. It becomes apparent that prior to Industry 4.0, the central focus revolved predominantly around leveraging technological progress to enhance efficiency, productivity, and economic prosperity. However, with the emergence of Industry 5.0, the spotlight shifts towards notions such as cross-cultural collaboration and the elevated importance of user-centric cognitive systems.

In addition, Industry 5.0 is corner-stoned by sustainability which strongly emphasizes efficient resource utilization, reuse, repurpose and recycle[1]. The third pilar in Industry 5.0 is resilience which refers to system robustness to ensure its rapid recovery or even new developments after disruptions[1]. All these above-mentioned perspectives necessitate a comprehensive shift in mindset from how humans tailor to technologies to what technologies can do to assist humans and benefit society in the long run.

To master this fundamental transition, the emergence of education is highlighted. Education in Industry 5.0 is especially critical since business will be facing:

- New Skill Requirements [21, 22]: Industry 5.0 will demand a different set of skills compared to the previous industrial revolutions. As jobs become more technologically sophisticated, there will be an increasing demand for employees who possess expertise in working with advanced technologies, programming, data analysis, and human-machine collaboration. Education and training programs need to be adapted to equip the workforce with these new skill requirements.

- Upskilling and Reskilling [21]: As automation and AI integration increase, some jobs may become obsolete or significantly transformed. This transition period requires a focus on upskilling and reskilling the existing workforce to prepare them for the new roles and responsibilities that emerge in Industry 5.0. Education will play a pivotal role in ensuring employability.

- Innovation and Creativity [23, 24]: While machines and AI can handle repetitive tasks and data processing efficiently, human creativity, innovation, and problem-solving abilities will remain highly valuable. Education should foster these human traits to enable individuals to contribute uniquely to Industry 5.0 by finding innovative solutions and providing creative insights.

- Adaptability and Lifelong Learning[24, 25]: The pace of technological change is accelerating, and job roles may evolve rapidly. Education needs to instill a mindset of adaptability and continuous learning in individuals. Lifelong learning will be essential for workers to stay relevant in their careers and for organizations to remain competitive.

- Cultural Shift and Acceptance[26, 27]: Transitioning from Industry 4.0 to 5.0 might require a cultural shift in the workplace. People may be resistant to change or fearful of new technologies. Education

can help in cultivating a positive mindset towards technology, fostering a culture of collaboration with machines, and promoting a growth-oriented outlook.

- Ethical and Social Considerations[28]: Industry 5.0 brings with it new ethical dilemmas and challenges, such as privacy concerns, data security, AI bias, and the impact of automation on employment. Education can emphasize ethical considerations and social responsibility to help individuals understand and address these issues effectively.

These points carry crucial significance for any business aiming to thrive in Industry 5.0. Nevertheless, they appear even more daunting for SMEs, given their inherent limitations, including financial constraints and a deficiency in current technological expertise, especially concerning its integration with human-centric principle. Tailored education specifically addressing the aforementioned aspects is of paramount importance for SMEs to fully harness the advantages offered by Industry 5.0.

III. EDUCATION FOR SMEs

Earlier research has asserted that SMEs often encounter challenges in recruiting competent workforce and are frequently burdened by skill gaps, impeding them from fully capitalizing on advantages offered by Industry 5.0. As technology progresses swiftly, SMEs run particularly the risk of lagging behind if they fail to promptly update the skills and competencies of their current employees. Furthermore, Industry 5.0 operates on a triple-helix approach, signifying that technological integration within SMEs must place greater emphasis on its potential benefits for not only human well-being but also the environment and the broader society.

Recognized as vital pillars of the global economy, SMEs possess the right to request specialized initiatives designed to enhance the skill sets of their existing workforce. These tailored programs facilitate ongoing learning, equipping employees to effectively tackle impending challenges. Furthermore, SMEs shoulder the responsibility of communicating their requirements to educational institutions, ensuring that the graduates they recruit are equipped with contemporary knowledge and skill contributing to the SMEs' seamless transition into the realm of Industry 5.0.

To meet the above expectations, an educational ecosystem is advocated. Table 1 provides typical stakeholders involved in this system.

TABLE I.   STAKEHOLDER OF EDUCATIONAL ECOSYSTEM

Stakeholder	Functions
Educational Institutions	Such as universities, colleges, and vocational schools offer educational content in the form of degree programs as well as specialized programs tailored to cater to the specific requirements of SMEs.
Research and Innovation Centers	Entities dedicated to research and innovation collaborate closely with SMEs to create customized programs that leverage their core expertise and cater to the unique needs of individual or a small group of SMEs.
Industry Associations	Such organizations often collaborate to identify the skill gaps and training needs of SMEs, advocating for relevant educational programs and facilitating connections between SMEs and educational providers.

In addition, in the process of crafting educational programs for SMEs, key partners such as standardization institutions, technology providers, financial institutions, and governmental agencies play a crucial role by offering essential contextual guidelines.

When designing customized education program for SMEs, it is essential to understand the authentic needs from SMEs as well as their inherent constraints. Also, it is equally vital that the education program is designed with alignment to the pace and path of SMEs' own growth to ensure the adjustment with their required rhythm of upskilling and ongoing learning. From the learners' perspective, following elements are therefore important to be consider when designing education program:

- what to learn: a curriculum specifically designed to address the needs and challenges faced by SMEs. The curriculum should focus on, i.e., industry trends, the sector's specific knowledge, best-practices, technologies, skills, and relevant tools that are applicable.

- How to learn: tailored education for SMEs would prioritize practical, hands-on training to equip participants with the essential skills efficiently. For instance, curriculum can be designed to cater various knowledge and management tiers, apply diverse learning methods such as workshops, technical training sessions, simulation-based learning, and real-world case studies. This will enable participants to directly apply their newfound knowledge to their roles.

- When to learn: learning at the right time ensures that SMEs acquire knowledge and skills that are directly applicable to their current and upcoming business needs. Providing learning opportunities when employees are most receptive enhances engagement and job satisfaction, which is imperative important in the SMEs' transition to Industry 5.0.

Over the years, numerous initiatives have been undertaken, resulting in the establishment of various ecosystems that facilitating the upskilling at European SMEs. Drawing from our experience, the inception of Industry 5.0 and its interconnected pillars of human-centricity, sustainability, and system resilience are natural result of technology-driven business and societal innovation in Europe.

A. TARGET

Project "Making Regional Manufacturing Globally Competitive" (TARGET) which carried out in the period of 2015-2018 has been focused its effort in manufacturing sector with providing tools to enhance capacity of manufacturing companies in Northern Periphery & Arctic (NPA) region to adapt and embrace new technologies and innovation. The primary obstacle during that period was the

maturity of the concept of digitalization for SMEs, juxtaposed with the complexity of comprehending Industry 4.0 technologies by those very SMEs.

Fig. 2 illustrates the TARGET toolbox, encompassing a quadruple perspective that encompasses "Application of New Technologies", "New Ideas and Thinking", "Business Model" and "Product Innovation".
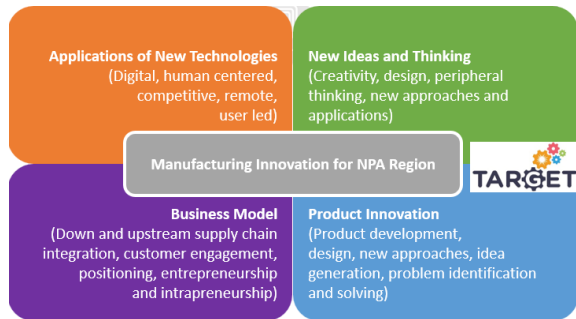

Figure 2. TARGET toolbox

Within this project, we have acknowledged the imperative of contextualizing the adoption of novel technologies within SMEs. This entails inquiring why these implementations should occur, a process achieved through the mapping of fresh product prospects, novel concepts, and innovative approaches to business generation. Moreover, TARGET advocates the notion that SMEs must extend their gaze beyond operational confines to guarantee the ultimate contentment of end customers. To delve deeper into the toolkit's components, we have elected to delineate the stages involved in aligning industrial requirements with potential technical solutions and/or tools, as demonstrated in Fig. 3.
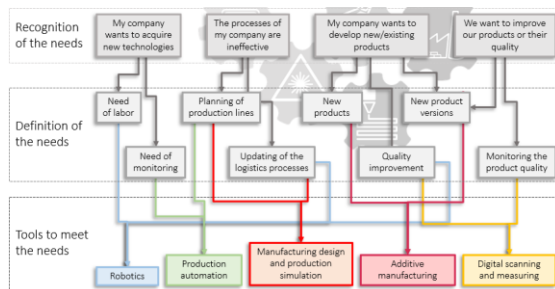

Figure 3. TARGET linking between needs and tools

The project provided with basic knowledge of key technologies relevant[1] for the SMEs. The platform served as a space for providing basic-level education to SMEs.

Furthermore, the project has yielded a number of notable insights, including the following key points:

- TARGET project consortium comprises universities, research institutions, and business associations, forming a comprehensive network that enables the consortium to engage with industry through a practical-oriented approach. This facilitates a swift alignment of problems with solutions, offering valuable assistance to SMEs.

- The sustainability of this consortium structure should be enhanced beyond the project's conclusion to ensure the ongoing development of the toolbox and its continued relevance to developing demands of businesses.

- Scaling up the outcomes is imperative to extend the benefits of the program beyond the geographical confines of the project region, thereby catering to a broader spectrum of SMEs.

B. TRINITY

Digital Technologies, Advanced Robotics and Increased Cyber-Security for Agile Production in Future European Manufacturing Ecosystems (TRINITY) is funded by EU Horizon 2020 program in "Digitising and transforming European industry and services: digital innovation hubs and platforms". The project has recently concluded its operational phase spanning from 2019 to 2023.

TRINITY is considered as one of the follow-ups of the TARGET, with the objective of establishing a network comprising diverse and collaborative local digital innovation hubs (DIHs). These DIHs consist of research centers, SMEs, and university groups, collectively encompassing a broad spectrum of expertise relevant to agile production. The driving force behind these hubs is advanced robotics, supported by digital tools, data privacy measures, and cybersecurity technologies.

Education has been the centerpiece of TRINITY. The project started with providing user cases already be proved to be relevant to industry. A systematic approach has been conducted to break down the solutions presented into technical manageable modules. A large amount of training material has been developed divided into different categories based on the learners' level of knowledge and management level. Fig. 4 illustrates the elements of TRINITY Training Platform. All training courses have a short introduction with specification of potential interests. System and technical specifications have been given to ease the learning and duplicating the modules in industrial practice[2].
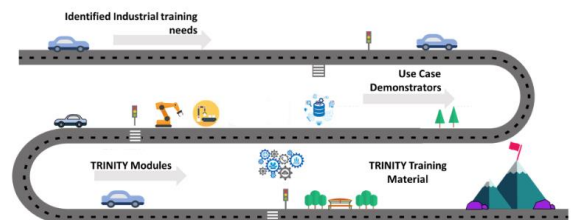

Figure 4. TRINITY Training Platform

Beyond its technological importance to SMEs, TRINITY addresses the intrinsic obstacle of funding constraints frequently encountered by SMEs. It achieves this by offering cascade funding, which allows selected businesses to seek financial support for the purpose of learning and implementing the core technologies central to TRINITY.

The experience gained through TRINITY project confirmed that it is imperative that SMEs engage themselves

[1] http://www.targetproject.eu/tools/

[2] https://trinity-trainingplatform.eu/

in multi-disciplinary, upscaled, high-competence network, i.e., Digital Innovation Hub (DIH). Further, ensuring the availability of comprehensive and practical learning materials holds utmost importance in facilitating efficient learning procedures. Nevertheless, the continuous utilization of DIHs by SMEs hinges on the sustainability of these hubs and their capacity to consistently update the knowledge they contain.

C. RoboDemo

Demonstrating New Generation Robotics and Smart Manufacturing to SMEs in the NPA Region (RoboDemo) is an on-going (2022-2025) project following the footsteps of TARGET and TRINITY. The project overall objective is to develop, optimize and pilot an agile cross-national technology transfer model to support companies (in the NPA area), combining different areas of expertise, to promote the adoption of smart manufacturing and Industry 4.0 technologies[3]. This model consists of five parts/steps – departing from a R&D institution's standpoint:

1. Becoming acquainted with the company's needs: Experts meet with key personnel from the company and investigate the current production process and identify problem points and bottlenecks.

2. Defining and preparing the content of the demonstration: Based on the evaluation of needs, a demonstration definition is produced, and a demonstration is prepared and tested at research partners' laboratory.

3. Piloting and demonstrations: In the third phase, the hardware (i.e., a robot) is taken to the company and installed as a part of the production process. Testing and knowledge transferring are conducted at the company's premise.

4. Simulations and modeling the benefits of technology: In cases where it is not possible to implement an onsite demonstration, a simulation model is developed to illustrate the functionality of the solution.

5. Documenting: The demonstration is reported to assist the company in finding the right technological applications to optimize their production process.

This technology transfer model has a special focus on creating learning-by-doing experience at the SMEs premises. When tailored demonstration is placed in an industrial environment, it is easy to create innovative spin-offs while the original ideas are tested out. Also, bottlenecks as well as opportunities could more easily be identified and discussed among the project participants and should finally form the basis in a future investment strategy.

D. International Cooperation

The importance of upskilling within SMEs plays a vital role in regional economies and is fundamental for achieving sustainable development both within Europe and on a global scale. Given that SMEs are important collaborators in supply chains, it is crucial to develop the transnational capabilities of these entities. A cross-border upskilling platform is vital for closing the capacity gap among diverse regions and nations.

Our earlier and on-going projects which building such upskilling platform are:

- BANOROB (2013-2015)[4]: is a Bosnian-Norwegian initiative.

- RoNo Cooperation for Virtual Manufacturing (2022-2023)[5]: Romanian-Norwegian initiative.

- Industry 5.0 enabled Smart Logistics (ongoing)[6]: Norwegian- Chinese initiative

- Smart Systems as A Tool for Reducing the Carbon Footprint of Green Industrial Technologies (on-going)[7]: Norwegian-Slovakia initiative.

- Promoting Cyber Security for Critical Infrastructure – PROCSI (on-going)[8]: Finnish-Norwegian-Latvia initiative

These projects have following common denominators:

- Project consortium: Principal participants encompass educational institutions, business associations, and SMEs.

- Curriculum development: Collaborative creation involving the exchange of existing curricula and the formulation of new ones based on industrial trends and needs analysis.

- Resource sharing: Encompassing sharing R&D personnel, laboratories, testing, and piloting capabilities.

- Digital cooperation platform [30]: Given the increasing focus on human-centricity in manufacturing, the development of a training platform that can cater to individual learning needs, personalized according to their knowledge level, and irrespective of their geographic locations, stands as a significant and impactful endeavor.

IV. SUMMARY AND CONCLUSION

The shift to Industry 5.0 poses amplified challenges for businesses, particularly SMEs, due to limited resources, awareness gaps, and skill shortages. Partnership with R&D institutions and business associations emerges as a beneficial approach for SMEs, aiding in skillful personnel recruitment and facilitating continuous learning. In shaping SME-tailored educational programs, a collaborative educational ecosystem involving key stakeholders is essential. Departing from SMEs' perspective and incorporating practical learning is crucial. Our research highlights the pivotal role of collaboration between businesses and R&D institutions as SMEs drive technological advancements and R&D

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[3] https://www.interreg-npa.eu/projects/funded-projects/project/254/

[4] https://site.uit.no/banorob/article/?option=com_content&view=article&id=24&Itemid=161
[5] https://www.ms.sapientia.ro/~EEAGrants/21-COP-0027-EN.html
[6] https://uit.no/research/arclog/project?pid=804715
[7] https://uit.no/research/arclog/project?pid=802136
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institutions require tangible input to continually shape a relevant curriculum.

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