

Societal Transformation Related to Emerging Technologies in Industry Through Bi-Lateral Collaboration

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Abstract: Emerging Industry 4.0 technologies—such as automation, additive manufacturing, and artificial intelligence—are accelerating the need for continuous upskilling in industrial workforces. While upskilling is not a new societal phenomenon, the current pace and breadth of technological change interact with national education systems, industrial structures, and funding models in ways that differ substantially across countries. This creates both challenges and opportunities for international collaboration in lifelong learning and work-integrated learning (WIL). This paper examines societal transformation related to emerging technologies through a bilateral lens, focusing on learning initiatives and institutional practices in Sweden and India. Drawing on observations and interactional collaboration between higher education institutions in both contexts, we illustrate how upskilling demands are shaped by differing national trajectories. For example, historical Swedish adult education initiatives—such as evening studies undertaken to respond to increasing internationalization—can be contrasted with contemporary patterns in India, where engineers often engage in weekend-based learning to meet rapidly evolving industrial competence needs. Despite the global nature of industrial markets, priorities regarding who funds upskilling (industry, academia, individuals, or the state), how learning time is allocated, and how competence development is evaluated vary across contexts. We benchmark a WIL-oriented model associated with Indian experiences against Swedish experiences of WIL and educational quality enhancement, including structured follow-up with participants (e.g., focus groups) to iteratively improve course design. Based on this comparative analysis, we propose an initial conceptual framework to support bilateral collaboration in upskilling emerging technologies. The framework highlights critical dimensions to align across contexts, including technology maturity, competence capability, and resource conditions such as time and financial support in both industry and academia. The paper concludes with a gap-oriented discussion of how virtual laboratories and shared e-learning platforms could enable scalable bilateral collaboration for work-integrated upskilling.

Keywords: Work-Integrated E-Learning; Work-Integrated Learning (WIL); Lifelong Learning; Industry 4.0 Upskilling; Reskilling, Virtual Laboratories; International/Bilateral Collaboration; Course Design and Evaluation.

1. Introduction

Emerging Industry 4.0 technologies—such as automation, additive manufacturing, and artificial intelligence—are accelerating the need for continuous upskilling in industrial workforces. While upskilling is not a new societal phenomenon, the current pace and breadth of technological change interact with national education systems, industrial structures, and funding models in ways that differ substantially across countries. This creates both challenges and opportunities for international collaboration in lifelong learning and work-integrated learning (WIL).

The diffusion of Industry 4.0 technologies, including automation, artificial intelligence, cyber-physical systems, and data-driven manufacturing, is fundamentally reshaping industrial work and competence requirements worldwide (Khan & Mourad, 2025). As production systems become increasingly complex and interconnected, industrial professionals are required to engage in continuous learning throughout their careers.

While lifelong learning has long been discussed in policy and educational discourse, the speed, complexity, and interdisciplinary of current technological change represent a qualitative shift compared to earlier industrial transitions (Asiedu & Tenakwah, 2025) (Forum, 2025). This shift challenges traditional models of education that assume a clear separation between formal education and professional practice.

Upskilling does not occur in isolation but is embedded within national education systems, industrial labor structures, cultural expectation, and funding mechanisms (Li, 2022). As a result, similar technological drivers may lead to markedly different institutional responses across countries. Understanding these differences is essential for designing effective international collaboration in work-integrated learning (WIL) and lifelong learning (LLL) (Zegwaard & Pretti, 2023).

This paper examines societal transformation related to emerging technologies through a bilateral lens, focusing on learning initiatives and institutional practices in Sweden and India. Drawing on observations and interactional collaboration between higher education institutions in both contexts, we illustrate how upskilling demands are shaped by differing national trajectories. For example, historical Swedish adult education initiatives—such as evening studies undertaken to respond to increasing internationalization—can be contrasted with contemporary patterns in India, where engineers often engage in weekend-based learning to meet rapidly evolving industrial competence needs. Despite the global nature of industrial markets, priorities regarding who funds upskilling (industry, academia, individuals, or the state), how learning time is allocated, and how competence development is evaluated vary across contexts.

This paper adopts a bilateral comparative perspective, focusing on Sweden and India, two contexts with strong engineering traditions and global industrial integration, yet distinct socio-institutional trajectories.

Through collaborative interactions between higher education institutions in both countries, the study explores how upskilling practices are organized, financed, and evaluated.

2. Background

2.1 Industry 4.0 and the Upskilling Imperative

Research consistently highlights that Industry 4.0 is not merely a technological transformation but also a profound workforce transformation (Li, 2022), which is significant for manufacturing SMEs in their strive to implement new emerging technologies (Onu, 2021). Challenges related to emerging technologies are the lack of skilled persons (Mittal et al., 2018). (Mittal, 2018) However, studies estimate that a significant proportion of current skills will become obsolete within a decade, requiring both reskilling and upskilling across industrial sectors (Forum, 2025). Recent literature emphasizes that effective upskilling must integrate technical competencies with transversal skills such as system thinking, adaptability, and digital literacy (Garcés, Sanz-Benloch, Montalbán-Domingo, & Díaz-Lantada, 2025). This has led to increased attention to learning models that combine academic knowledge with workplace practice.

2.2 Work-Integrated Learning (WIL)

Work-Integrated Learning (WIL) is widely regarded as a pedagogical and institutional approach that intentionally integrates learning and work through structured collaboration between higher education and industry (Zegwaard & Pretti, 2023). It encompasses a range of models including project-based learning, professional courses, and work-based education. However, comparative research demonstrates that WIL is implemented differently across national contexts, shaped by regulatory frameworks, labor-market conditions, and institutional cultures (Sunnemark, o.a., 2024). These differences affect funding responsibility, learning time allocation, and quality assurance practices. Involving students actively in WIL enhances professional growth, offering scalable alternatives to placements (cases) and contribute to learning by doing (Garner, 2026) (Garner & Wilson, 2026). However, it is at least three different stakeholders in the WIL process – the employer, the employees and the education provider (Rikala P, 2024). The students might be regular program students, employees and job seeking persons (Braun Greta, 2024), which can challenge the WIL organisation and add a possibility to engage the students with different backgrounds and experiences (Garner & Wilsson, 2026). BITS Pilani WILP model, for example, has a mature and large-scale system, it was established in the early 1970s with strong integration with industry, around 95% of campus students move into industry and employers actively sponsor and support education.

2.3 National Trajectories of Adult and Continuing Education

Sweden has long tradition of adult and continuing education supported by public policy, including structured evening studies and employer-supported learning initiatives aimed at supporting industrial transformation and social inclusion (Lundh Snis, Per, & Irene, 2025). In contrast, temporary Indian upskilling patterns often reflect

rapid industrial expansion combined with competitive labor markets. Engineers frequently engage in weekend-based on parallel learning, often driven by individual or employer initiative, to maintain employability in fast-evolving technological domain (Warnhoff, 2025). However, the emerging technologies are global, and it is important that training contribute to bridging the competence gap and is valuable for the company (Johansen & Akay, 2022) and the introduction of new technologies in combination with development of skills needs to be continuously discussed (Brynjolfsson, 1993)

3. Methodology

We benchmark a WIL-oriented model associated with Indian experiences against Swedish experiences of WIL and educational quality enhancement, including structured follow-up with participants (e.g., focus groups) to iteratively improve course design. Based on this comparative analysis, we propose an initial conceptual framework to support bilateral collaboration in upskilling emerging technologies.

This study employs a qualitative, exploratory, and comparative approach, consistent with prior research on WIL and international education collaboration (Braun Greta, 2024). The aim of the study is to analyze analytic generalization rather than statistical representativeness when it comes to understanding the similarities and differences between the two national contexts.

The analysis draws on:

- Observations from bilateral collaboration between higher education institutions in Sweden and India
- Interaction with educators, administrators, and industry-aligned partners
- Reflections on implemented or piloted WIL-oriented initiatives
- Structured follow-up activities, including focus groups used for educational quality enhancement (Sunnemark, et al., 2024)

4. Comparative Findings: Sweden and India

This comparative has been done based on literature, observations, discussions, and recently focus group reflections where the authors have had the opportunity to visit both countries and our respective faculties.

BITS Pilani WLP model is mature, large-scale education system established in the early 1970s, currently serves ten of thousands of students and demonstrates a strong alignment between education and industry needs. A key feature is its high employability outcome, with approximately 95% of campus students transitioning into industry, supported by active employer engagement in education.

Jönköping University (JTH) and University West (HV) both implement Work-Integrated Learning (WIL), but with distinct emphases. At JTH, WIL is primarily embedded through CDIO-based engineering education, project-based learning, and structured industry collaboration (e.g., host company programs), enabling students to engage in real-world challenges while remaining largely campus-based (Berglund, et al., 2008). In contrast, University West adopts WIL as a core institutional philosophy, integrating academic and workplace learning across education, research, and collaboration, and emphasizing reflection, active participation, the co-creation of knowledge between academia and society. While JTH focuses on innovation-driven projects and CDIO-aligned competences development, HV provides a more holistic and a research field (Areskoug Josefsson, et al., 2024). Table 1 showed a comparison between BITS Pilani, JU and HV, the first column indicates the dimensions based on meetings and a recently focus group. The main differences highlighted are: The Role of Industry, the scale and flexibility, the Pedagogical Focus, the Students Profile, and the Business Model.

4.1 The Role of Industry: Funding Responsibility and Degree of Work Integration

Funding models vary markedly across contexts. Swedish WIL initiatives typically involve shared responsibility between the state, higher education institutions, and employers, whereas in India funding is often shared between industry and individuals, with limited public support for continuing professional education (Asiedu & Tenakwah, 2025). BITS WILP is Fully work-integrated; employment is mandatory and the workplace is the primary learning environment, and employers co-own the education (funding, mentoring, infrastructure). While JTH model is partially integrated and has strong project-based collaboration but is still mainly campus-centered. Employers act as collaborators in projects and innovation activities. HV model is systematically integrated; work-

based learning is embedded but not always tied to employment and employers are co-creators of learning within a structured WIL framework.

4.2 The Scale and Flexibility: Organization of Learning Time

In the Swedish context, upskilling is often embedded within formal educational structures, including part-time and evening studies supported by employers or public funding, reflecting an institutionalized commitment to lifelong learning (Lundh Snis, et al., 2025). In contrast, Indian professionals frequently engage in weekend-based or parallel learning while employed full-time. These arrangements provide flexibility but also place significant responsibility on individuals to manage learning time alongside professional demands (Warnhoff, 2025). Regarding BITS WILP has a large- scale, moderate flexibility (blended and project-based), while HV has smaller scale, increasing flexibility but still more structured than WILP.

4.3 The Pedagogical Focus, the Student Profile and Education Quality Enhancement

According to the findings based on Table 1, BITS WILP model has experience-driven, mentor based, real industrial problem solving and the student profile is employee-students (working professionals). JTH has a pedagogical focus on CDIO, innovation, theory and practice and the student profile is traditional full-time students with exposure. The HV model pedagogical focuses on reflection-driven WIL pedagogy integrating theory and practice. The student profile is mixed (students and practitioners), but less systematically employment based. Swedish WIL models commonly include systematic follow-up mechanisms such as course evaluations and focus groups, enabling iterative educational improvement (Sunnemark, et al., 2024). Indian models tend to prioritize immediate industrial relevance and skill acquisition, sometimes with less formalized academic quality assurance but strong alignment to industry needs (Warnhoff, 2025)

4.4 The Business Model

The BITS WILP model had Company-funded education with clear ROI, while JTH business model has public funding + project-based external funding (EU/regional) and structured trainee programs, and the HV business model has public funding with partial employer co-financing and large-scale industry engagement. Both JTH and HV have similar business model and common trainee programmes and courses.

Table 1: Comparison of dimensions between India vs Sweden

Dimension	BITS Pilani – WILP	Jönköping University (JTH/JU)	University West (HV)
Overall Model	Fully work-integrated education system at scale (since 1970s)	Predominantly campus-based with project and industry collaboration elements	Explicit Work-Integrated Learning (WIL) university model (core identity)
Scale & Maturity	Very large-scale (tens of thousands), long-established	Medium scale, strong program-level innovations (e.g., MASTech)	Mature WIL model in Sweden, but smaller scale than WILP
Entry Requirement	Employment mandatory (students are working professionals)	No employment requirement; students are full-time learners	Mixed: students + professionals, but employment not always mandatory
Industry Integration	Very strong and systemic (employers' co-owned education)	Strong but project-based (partners, Science Park, industry)	Strong, institutionalized collaboration with public and private sectors
Role of Employers	Employers must sponsor, mentor, and provide learning environments	Employers act as project partners, case providers, advisors	Employers act as co-creators of learning, often embedded in courses
Learning Arena	Workplace = primary learning lab	Hybrid: campus labs + Living Labs + industry projects	Workplace-based learning integrated with academic study
Pedagogical Approach	Situated learning + PBL + mentor-based learning + Immersion elements	CDIO + PBL + Human-Centered Design + Living Lab approaches	WIL pedagogy: reflection + work practice integration

Dimension	BITS Pilani – WILP	Jönköping University (JTH/JU)	University West (HV)
Online Education	Workplace learning Remote/online teaching Physical and virtual labs Teaching staff Includes both academic faculty and industry experts	Teaching staff Includes both academic faculty and industry workers	Teaching staff Includes both academic faculty and industry workers
Student Role	Employee-student (dual identity)	Primarily student, increasingly exposed to real-world contexts	Mix of student + practitioner, depending on program
Faculty Role	Continuous industry supervision + curriculum feedback loop	Faculty guide projects, research integration, and industry collaboration	Faculty facilitate reflection between theory and practice
Curriculum Development	Direct feedback from industry practice continuously integrated	Industry input present but less systematically embedded	Strong integration of practice-based insights into curricula
Programme Formats	- Degrees (2–5 years)	- Bachelor/Master programs	- Degrees + professional education
	- Certificates	- Some professional courses	- Short courses and upskilling
	- Cluster education	- Emerging lifelong learning formats	- Emerging lifelong learning formats
Flexibility	Highly flexible, asynchronous, designed for working professionals	Moderate flexibility; some blended and online learning	Increasing flexibility, but less than WILP
Lifelong Learning (LLL)	Core strategic focus	Growing importance (aligned with EU strategies)	Strong orientation toward continuous professional development
Use of Technology	AI tools, simulations, digital platforms	Strong in engineering tools, prototyping, simulation	Applied digital tools, but less emphasis on advanced AI in learning
Infrastructure	Workplace as lab + supplementary competence centers	Advanced engineering labs + Living Labs (e.g., Assistive Tech)	Workplace + university facilities; strong practice environments
Assessment Challenge	Measuring workplace learning outcomes is still a challenge	Assessment aligned with CDIO/ILOs; less workplace-based assessment	Emphasis on reflection-based assessment, but similar challenges
Industry engagement and Business Model	Company-funded education (high ROI expectation) High competition for skilled employees	Mostly public-funded education + project funding (EU, regional). Large-scale industry engagement.	Public funding + some employer co-financing. Large-scale industry engagement.
Impact Evidence	Strong quantitative results (efficiency, savings, innovation outcomes)	Impact visible on projects, student outcomes, research outputs	Impact on regional development and workforce competence
Unique Strength	Full integration of education-work-industry at scale	Integration of education, research, and innovation	Institutionalized WIL pedagogy and reflection-based learning
Key Limitation	Scalability relies on strong employer ecosystem	Not yet fully work-embedded (employment not required)	Less scale and less deep integration into company structures than WILP

5. Benchmarking Work-Integrated Learning Models

Benchmarking Indian WIL-oriented practices against Swedish quality-enhancement approaches reveals complementary strengths. Indian models demonstrate high responsiveness to rapid industrial change, while Swedish models emphasize pedagogical structure, reflection, and institutional learning (Braun Greta, 2024) (Zegwaard & Pretti, 2023). This comparison suggests that bilateral collaboration can benefit from combining flexibility with systematic quality assurance.

6. A Preliminary Conceptual Framework for Bilateral Upskilling Collaboration

Based on comparative analysis, an initial conceptual framework is proposed. The framework identifies three key alignment dimensions:

1. Technology Maturity: Stability versus rapid evolution of industrial technologies (Khan & Mourad, 2025)
2. Competence Capability: Existing skill baselines and professional experience (Garcés, et al., 2025).
3. Resource Conditions: Time allocation, financial support, and institutional capacity (Asiedu & Tenakwah, 2025)

Explicit alignment across these dimensions is necessary to avoid uncritical transfer of single-context educational models.

7. Discussion and Conclusions

The findings underscore that upskilling challenges are global, but institutional responses are locally shaped. WIL emerges not only as a pedagogical approach but as an interface between societal transformation, industrial change, and educational governance (Zegwaard & Pretti, 2023) (Lundh Snis, et al., 2025). Bilateral collaboration offers opportunities for mutual institutional learning, rather than one-directional knowledge transfer.

7.1 Future Opportunities: Key Challenges and Reflections for Sweden

Transferring the WILP model to Sweden faces structural challenges, including lower company incentives to sponsor education, limited SME engagement, and a tendency to address skills shortages through hiring rather than training, which puts traditional degree programs at risk of losing relevance as skills gain importance. Rather than replicate WILP, the discussion highlights the need for a context-adapted Swedish WIL model that maintains strong integration between education and the workplace while aligning with local economic and industrial conditions. Key opportunities include developing SME-oriented models, leveraging applied sciences and AI-enhanced learning, and using WIL to support industrial transformation and international collaboration.

Virtual laboratories and shared e-learning platforms are increasingly recognized as enabling infrastructures for scalable, international WIL collaboration (Sellber & Mads, 2024) (Zhang & Yin, 2024). Such environments can support asynchronous learning, shared curriculum development, and reduced dependency on physical co-location. However, research also highlights the need for robust assessment frameworks and contextual adaptations to ensure educational quality and relevance (Dominik, et al., 2023).

7.2 Conclusions

This paper has examined industry 4.0-driven upskilling through a bilateral comparison of Sweden and India. Differences in learning organizations, funding responsibility, and quality assurance highlight the importance of context-sensitive WIL models. The proposed framework provides a structured foundation for future bilateral collaboration. The BITS WILP model shows that large-scale, industry-integrated education is both feasible and highly impactful, generating interest in adapting a similar approach to developed economies like Sweden. Key success factors include strong employer engagement and funding, flexible learning formats, real industrial problem integration, and continuous mentorship. However, the conclusion emphasizes that while WIL and lifelong learning will be essential for future education systems, their implementation in Sweden requires system-level adaptation, new incentive structures, and stronger commitment from industry partners

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Ethics Declarations

Ethical clearance was not required for the research.

AI Declarations

Copilot was used to structure the paper and improve the language.

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