Lifelong Learning for Career Sustainability: A Grounded Framework for Indian Early Career Engineers

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Abstract

The process of becoming an industry-ready engineer does not seem to be an easy task; it involves the acquisition of lifelong learning (LLL) even after placement in the industry. To keep the early career engineers (ECEs) sustainable in the industry, it is essential to know how the ECEs perceive and apply LLL. This study, part of an ongoing research, focuses on the role of LLL in shaping future engineers. This grounded research uses qualitative methods. The data was collected (n=100) from the engineering industry, mainly from early career engineers, managers, and human resource officers, through semi-structured interviews. The results show that LLL, one of the skills most demanded by the industry, was partially used without careful consideration (applicability) by ECEs. The differences in the awareness and use of LLL need more efforts for future-proofing and sustaining their careers as useful work tools. This study signifies the need to acquire feedback from the ECEs, as these active agents would help gather first-hand knowledge, yielding a better understanding, benefiting not only the new entrants but also the industry. The industry will gain a workforce of ECEs capable of contributing directly and effectively through TVCs, optimizing resources like training, mentorship, and digital tools to facilitate seamless integration into Industry 4.0 environments.

Keywords: *Lifelong learning (LLL), Early Career Engineers (ECEs), Transversal Competencies, Career Sustainability.*

1. Introduction

Rapid technological advancements and shifting Industry 4.0 demands challenge early-career engineers (ECEs) to develop adaptable, transversal competencies (TVCs) beyond core technical skills to ensure career sustainability (Sofiadin, 2022; Stef & Mirea, 2021; Wheebox et al., 2023). In this dynamic environment, ECEs must engage in lifelong learning (LLL) to continuously acquire, unlearn, and relearn skills, aligning with evolving tools, techniques, and market expectations (Van Den Broeck et al., 2022; Cruz et al., 2020). LLL fosters decision-making, active participation, and updated domain knowledge, enabling ECEs to navigate workplace complexities and contribute to professional and societal goals (Martinez-Mediano & Lord, 2012). However, employability gaps persist, necessitating a nuanced understanding of how LLL supports career sustainability in engineering industry contexts. This study employs grounded theory to iteratively explore ECEs' lived experiences (Charmaz, 2025), generating the LLL-career sustainability dynamics to elucidate the interplay of continuous learning, professional growth, and sustainable careers, with global applicability due to MNCs' international culture. By addressing these dynamics, this paper offers insights for academia, industry, and policymakers to enhance ECE sustenance.

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2. Background

LLL enables engineers to adapt to rapid technological advancements, enhance professional development, and sustain career competitiveness in Industry 4.0 by fostering and that apply across diverse workplace contexts (Aleksić et al., 2022; Nimmi et al., 2021; Kirby et al., 2010). TVCs are transferable due to their versatility, allowing ECEs to navigate evolving job markets, innovate solutions, and collaborate effectively in MNCs with globalized cultures (Van Den Broeck et al., 2022). LLL extends beyond formal education, encompassing workplace, community, and self-directed learning (Lang 2023; Walters 2021). Since the 1970s, LLL has evolved from self-regulated learning (Zimmerman, 2008) to self-directed adult education in the 1980s and informal learning in professional settings by the 1990s (Candy, 1991). Its complexity, shaped by diverse definitions across contexts, underscores the need for constructivist Grounded Theory (GT) to explore LLL's role in career sustainability for ECEs through iterative, context-specific data analysis (Aspin & Chapman 2007; Charmaz, 2025). This study leverages GT to develop the LLL - career sustainability dynamics, examining how LLL and TVCs foster sustainable careers in the engineering industries.

2.1 Perspectives on LLL

Governments and educational institutions brought forth Policy frameworks, such as the UNESCO (Atchoarena, 2022) recommendation on lifelong learning (adopted in 1976 and revised in 1997, 2017 and 2022), European Commission's Lifelong Learning Strategy, 2000 (EUR-Lex, 2025), UK framework for lifelong learning (Government Office for Science, 2017), and Australian lifelong learning policy (Cummins & Kunkel, 2015), which emphasise the importance of access to learning opportunities for all people, regardless of their age, background, or circumstances. Industry-specific LLL policies for professional development, like OECD (2010), focus more on the enhancement of productivity through a workforce that embraces LLL. The recent policies establish LLL as a strategy to establish an inclusive, sustainable, and universal LLL system (Mlambo et al., 2021; Jeffryes & Lafferty, 2012). These attempts are to bridge the skills gap, promote inclusive learning opportunities, and empower individuals to acclimatise to the fluctuating industry demands.

2.2 Research Gap

For the past ten years, researchers have talked about the significance and function of LLL in the workplace (Yap and Tan, 2022; Nimmi et al., 2021; Mlambo et al., 2021; Jeffryes & Lafferty, 2012). Although the works on LLL have increased the understanding of all the stakeholders (industry, employers, and employees) yet its understanding and usage from the perspective of ECEs, their immediate bosses, and HRs and managers needs to be looked at. Various researchers (Table I) have indicated that LLL is not duly utilised, though it seems to be an indispensable skill.

Table I. Select journal articles to establish the gap in engineering industry research.

Population	Themes/Focus	Future Implications	Author, Year
Engineering graduate students	Employability; Learning and competency assessment; Work-integrated learning	Industry working perspective outside the curriculum; Industry feedback and inclusivity; Task-based competency development	Jeffryes & Lafferty, 2012 Seniuk Cicek et al., 2016 Nimmi et al., 2021 Vailasseri et al., 2021
Engineering graduates/ interns	Multidisciplinary teams; Information age learning; Sustainable employment; work readiness	Competency assessment; LLL industry dimensions; Updated, shareable information; Socio-economic impacts	Ladesic et al., 2012 Naimpally et al., 2012 Chakrabarti et al., 2021 Aleksić et al., 2022
Engineers	Application in industry 4.0; Drivers and barriers; Transversal competencies and sustainability	Multiple engineering roles; Same issues in other industries; Importance of competencies in the shopfloors; Industry-specific factors	Ismaili et al., 2025 Narayanan & Emad, 2022 Sangwan & Venugopal, 2022 Park & Kim, 2023
Other (Nurses, Medical students, Librarians)	Continuing professional development (CPD); Medical students' orientation; Competency and work readiness	LLL in other professions; Focused orientation; Other domains of LLL	Wetzel et al., 2010 Mahoney, 2017 Mlambo et al., 2021

3. Methodology

This study employs a constructivist Grounded Theory (GT) approach exploring lifelong learning and career sustainability among ECEs in four engineering industries (Charmaz, 2025). Data was collected from 100 professionals, placed in the top four industries that induct more ECEs in India such as IT, Mechanical, Civil and Electrical engineering (Wheebox et al., 2023). Constructivist

GT emphasizes the co-construction of knowledge between researchers and participants, acknowledging subjective experiences and iterative processes to generate a contextualized theory grounded in data (Charmaz, 2025). The methodology unfolded through three iterative rounds of data collection and analysis, accompanied by an intertwined literature review, which allowed emergent themes to guide the research process while refining codes and categories to capture the evolving dynamics of lifelong learning and career sustainability.

3.1 Iterative Literature Review

The literature review was conducted iteratively, aligning with constructivist GT's emphasis on flexibility and responsiveness to emerging data (Charmaz 2014). In the initial phase of literature review, a pre-review identified key concepts, such as employability gaps, Industry 4.0 skill requirements, and career sustainability, drawing on sources like Sangwan and Venugopal (2022) for Industry 4.0 competencies and Savickas (2013) for career adaptability. During Round 1, the review expanded to include studies on transversal competencies (TVCs) and MNC workplace learning, informed by initial codes (e.g., "*seeking training*"). In Round 2, focused codes (e.g., "*pursuing self-directed learning*") prompted deeper engagement with literature on lifelong learning and professional development (Johri & Olds 2011). By Round 3, the review integrated advanced concepts of career sustainability and global employability, refining the framework as new dynamics emerged (Corbin & Strauss 2015). This iterative process ensured literature-informed, but did not constrain, the emergent LLL career sustainability dynamics.

3.2 Data Collection and Analysis

Data collection occurred over three iterative rounds, involving semi-structured interviews with ECEs (n=50), Managers (n=30), and HRs (n=20). Each round built on the previous, refining codes, eliminating less relevant ones, and culminating in a new dynamic of lifelong learning and career sustainability.

Round 1: Initial Exploration

Semi-structured interviews explored employability challenges and learning behaviors in Industry 4.0 contexts. Initial coding generated codes like "*seeking training*," "*learning on-the-job*," and "*adapting to tools*," reflecting novice struggles (Charmaz, 2025). Subcategories (e.g., "*engaging in structured training*") emerged, but codes unrelated to lifelong learning (e.g., "*managing workplace stress*") were set aside to focus on skill acquisition. The literature review was updated to include TVC development (Sangwan & Venugopal, 2022).

Round 2: Focused Refinement

Follow-up interviews targeted emerging themes, such as self-directed learning in the early stages of ECE careers. Focused coding refined codes to "*pursuing self-directed learning*," "*exploring digital tools*," and "*adapting proactively*," while less relevant codes (e.g., "*following team norms*") were discarded (Corbin & Strauss 2015). Subcategories like "*exploring Industry 4.0 tools*" highlighted lifelong learning's role in competency progression. The literature review incorporated lifelong learning frameworks (Johri & Olds 2011), guiding theoretical sampling for Round 3.

Round 3: Theoretical Integration

Interviews with more stakeholders validated findings, focusing on ECEs' workplace learning patterns. Theoretical coding produced codes like "*mastering continuous learning*," "*innovating independently,*" and "*sustaining career growth*," with irrelevant codes (e.g., "*managing client expectations*") eliminated (Charmaz, 2025). A new dynamic emerged: lifelong learning as a core mechanism for career sustainability, enabling ECEs to adapt to skill shifts in global MNC settings (Savickas, 2013). Subcategories (e.g., "*sustaining long-term career*") informed the LLL career sustainability model's "*competency outcomes*" and "*theoretical synthesis*," with global applicability due to MNCs' international culture (Jackson, 2019).

Theoretical sampling guided participant selection across rounds, targeting ECEs at different career stages and stakeholders to elaborate emerging categories (Charmaz, 2025). Data collection ceased when theoretical saturation was reached in Round 3, as no new insights on lifelong learning or career sustainability emerged (Corbin & Strauss, 2015). Constant comparison ensured codes and subcategories were iteratively refined, leading to the LLL career sustainability model's framework, which integrates career enablers, stages, readiness, and emergent theory.

To ensure rigor, we employed memo-writing to document analytical decisions, member checking to validate findings with participants, and peer debriefing to refine interpretations (Charmaz, 2025). The iterative interplay of data collection, coding, and literature review ensured the LLL career sustainability model was grounded in ECEs' lived experiences while addressing Industry 4.0 and global employability contexts.

4. Results and Discussion

4.1 Iterative Insights into Lifelong Learning and Career Sustainability

Through three iterative rounds of data collection and analysis, an iterative literature review engaged with existing lifelong learning (LLL) models - such as the Four Pillars of Learning (Delors , 1996), Andragogy (Knowles, 1980), Heutagogy (Hase & Kenyon 2000), Self-Directed Learning, Reflective Learning, and Illeris's workplace learning model (Illeris, 2003) - which emphasize self-directed, experiential, and reflective learning for competencies like knowing, doing, living together, and being (Laal & Salamati 2012; Chakrabarti et al., 2021; Lang, 2023). These models, while robust, lack specificity for early-career engineers (ECEs) navigating Industry 4.0 challenges in Indian MNCs. This study extends prior work by integrating TVCs awareness into a context-specific Lifelong Learning and Career Sustainability Dynamics, derived from iterative data analysis (Charmaz, 2025) that underpin LLL's role in career sustainability, paving the way for the emergent model.

4.2 Influencing Factors

Data analysis identified factors shaping ECEs' LLL engagement, extending beyond formal education to self-directed and informal learning. ECEs continuously update technical knowledge

and TVCs, aligning prior learning with Industry 4.0 skills (e.g., AI, automation) and MNC culture, driven by personal motivation, resource access, and mentorship (Walters, 2021). Supportive workplace environments foster self-directed learning, skill-based training, collaborative learning, reflective practices, and mentoring, enhancing TVCs' transferability across diverse contexts (Sofiadin, 2022; Yap & Tan 2022; Dawe et al., 2021). Formal learning occurs through targeted training led by seniors, while informal learning emerges via colleague interactions and online resources, amplifying professional growth and career sustainability.

4.3 Lifelong Learning and Technology

LLL equips ECEs with current skills to meet Industry 4.0 demands, yet rapid technological advancements challenge skill relevance (O'Neill et al., 2015). Data revealed ECEs' struggles to keep pace with evolving technologies, necessitating continuous learning to sustain employability. MNCs facilitate LLL through internal training, certifications, and tuition support, enhancing TVCs' transferability in global settings (Lang, 2023; Dawe et al., 2021). Online platforms, MOOCs, webinars, and virtual classrooms enable self-paced, interactive learning, connecting ECEs globally (Yap & Tan, 2022). These technological affordances, identified through iterative coding, strengthen LLL's role in career sustainability, informing the emergent Lifelong Learning and Career Sustainability Dynamics.

4.4 Iterative Rounds of Data Analysis

Iterative data analysis across three rounds of constructivist GT revealed a progressive emergence of learning theories, culminating in the Lifelong learning and career sustainability dynamics framework for ECEs in Indian engineering industries (Charmaz, 2025). Each round comprising semi-structured interviews generated codes that aligned with some established theories, with residual codes driving further exploration, ultimately synthesizing a novel model addressing LLL's role in career sustainability amidst Industry 4.0 challenges.

Round 1: Initial coding of interviews produced codes like "*seeking relevant training*" and "*motivated by career goals*," aligning with Adult Learning Theory's emphasis on self-directed, context-driven learning (Hedin, 2010; Allen et al., 2022). Subcategories (e.g., "*engaging in goal-oriented learning*") highlighted ECEs' need for practical knowledge in MNC settings. Codes unrelated to LLL (e.g., "*managing workplace stress*") were discarded, but residual codes (e.g., "*learning through practice*") suggested experiential elements, prompting Round 2.

Round 2: Interviews refined codes to "*reflecting on tasks*" and "*solving problems hands-on*," resonating with Experiential Learning Theory's focus on learning through authentic experiences (Kolb & Kolb 2017; Austin & Rust 2015). Subcategories (e.g., "*learning via workplace challenges*") underscored TVCs like problem-solving and adaptability. Codes like "*following team norms*" were eliminated, but residual codes (e.g., "*mastering specific skills*") pointed to competency-based learning, necessitating Round 3.

Round 3: Interviews yielded codes like "*developing targeted skills*" and "*achieving competency goals*," aligning with Competency Theory's emphasis on context-specific skill development (Škrinjarić 2022). Subcategories (e.g., "*integrating skills for Industry 4.0*") highlighted TVCs'

transferability across MNC contexts. Residual codes (e.g., "*sustaining career through continuous learning*") remained, indicating a broader dynamic.

4.5 Emergent Framework: Lifelong Learning and Early-Career Sustainability Dynamics

Despite three rounds, residual codes (e.g., "*adapting to rapid changes*," "*fostering long-term employability*") revealed a dynamic interplay of Lifelong Learning and Career Sustainability. This framework positions ECEs as agents of self-directed learning, integrating reflection, problem-solving, and motivation to develop TVCs (e.g., adaptability, digital literacy) for Industry 4.0 demands. LLL serves as both a process (active engagement, feedback-driven growth) and a product (sustainable careers, efficient workplaces), enabling ECEs to navigate fluctuating markets and achieve professional goals through continuous, context-specific skill development (Allen et al., 2022; Škrinjarić, 2022).

Analysis of the data helped to classify LLL in the industry into three major themes: competency enhancement, workplace learning barriers, and professional impact (Table II).

Table II. LLL and career sustainability dynamics

Context	Competency Enhancement	Workplace Learning Barriers	Professional Impact	Career Sustainability
ECEs	Updated domain knowledge	Readiness to changes	Current/future problems preparedness	Professional Relevance
Managers and HRs	Relevant workplace skills development	Relevant skill sustenance		
ECEs	Role and teamwork readiness	Workplace constrains	Situational shape shifting	Adaptability and Versatility
Managers and HRs	Contextualised critical thinking and problem-solving use	Practical applications/situations		
ECEs	Novel solutions initiatives	Time constraints and deadlines	New ideas and solutions generation	Innovation
Managers and HRs	Continuous learning commitment	Lack of workplace learning and new thinking		
ECEs	Opinions acceptance	Closed mind-set	Reflective practices adoption	Continuous Improvement
Managers and HRs	Error learning Challenging tasks readiness	Prejudiced and self-centred actions		
ECEs	Stress handling	Tight schedule, urgent deadlines, complex problems	Better work-life balance	Resilience

Managers and HRs	Time management	Inefficient work pattern and work division		
ECEs	Industry changes awareness	Lack of awareness	Industry demands acceptance	Industry Demands
Managers and HRs	Industry-need specific shape-shifting	Ignorance and reluctance to understand and embrace the changes		
ECEs	Openness to change Industry networking	Inability to contact and connect	Better engineer, better workforce	Futureproofing
Managers and HRs	Professional bodies membership	Unawareness among the ECEs		
ECEs	Global issues awareness	Task/ Job specific	Social problems engagement	Global Challenges
Managers and HRs	Specific skills awareness challenges	Time/role constraints		
ECEs	Sense of purpose	Unawareness of LLL	Willingness to learn and grow	Personal Fulfilment
Managers and HRs	Creative streak	Time constraints, task/ job specific		

4.5.1 Competency Enhancement

LLL benefits to the ECEs include increased employability, improved cognitive function, enhanced creativity, expanded social networks, and improved quality of life (Zhang et al., 2010; Laal & Salamati, 2012). The study brings forth multifaceted benefits of LLL, such as keeping up with technological advancements, enhancing professional development, adapting to changing job demands, broadening career opportunities, and improving problem-solving skills. ECEs learn from human and non-human resources; they freely but with a purpose engage in discussions with experts and peers, read books and other materials, watch videos, and pursue new hobbies and interests.

Keeping up with Technological Advancements

The study supports the need to learn about the constantly evolving technologies and techniques (Sangwan & Venugopal, 2022) in industries like AI and data analysis. Furthermore, ECEs, HRs, and managers are of the opinion that engineers must maintain up-to-date knowledge not only to remain relevant but also to enhance their contributive relevance to the industry. The acquisition of new programming languages and the development of tools are critical to sustaining the job, avail the opportunities, and develop professionally. HRs are always on the lookout for individuals who possess the latest skills and knowledge. ECEs without the latest technological advancements may find it difficult to survive in the industry.

"I watch YouTube videos and read blogs to learn new tech like AI; it helps me stay useful at work." - ECE21
"We look for engineers who know the latest tools; it makes them ready for big projects." - HR5
"Engineers learning new technology help us finish projects faster." - M12

In addition to their job-related activities and industry-provided training, ECEs invest time beyond regular working hours to learn about new trends from different sources using different methods. Managers acknowledge and support their learning by giving due credit. The managers noted that such learners achieved more in their careers. At times, this trend of keeping up with the latest technological advancements in the field decreases when ECEs get a different role or job opportunity, which has a detrimental effect on the overall progress of the organisation.

Enhancing Professional Development

Professional development, a continuous process of acquiring new knowledge, skills, and experiences, enhances their competence and sustainability in their engineering field (Aleksić et al., 2022; Dawe et al., 2021). Our results add that technical skills enhancement and soft skills development can be achieved by continuous learning using industry exposure, networking, mentoring and guidance, professional memberships, and associations. ECEs acknowledge learning through observing the ways of others, noting down setback situations, and paying close attention to the ways problems are addressed and solved by the managers.

"I learn from my seniors' tips and join webinars; it makes me better at my job." - ECE42
"Engineers who keep learning show they're serious about growing in their career." - HR17
"Learning new skills makes our team stronger and more professional." - M8

HRs and managers prefer individuals who stay proactive, curious, and open to learning. Commitment of ECEs to LLL convinces their HRs and managers of their dedication to their profession and willingness to go the extra mile to enhance their skills and knowledge. Enhanced professional development ensures their career sustainability in the industry.

Adapting to Changing Job Demands

HRs and managers find the job demands and roles of the engineer constantly evolving; LLL helps individuals to adapt to these changes by providing them with the skills and knowledge essential to switch between different roles. The majority of ECEs feel that they can adapt to any work conditions; however, they think that switching job roles would be difficult, and they also fear the number of efforts needed to learn about the new job role.

"Learning new skills helps me handle different tasks, but changing roles feels tough…" - ECE33
"In them (ECEs) who learn fast would take on any role and grow quickly…" - HR9
"Engineers who adapt to new roles keep our projects running smoothly." - M25

HRs and managers think that the ECEs with transversal competencies, especially LLL skills, can switch between different roles easily. According to them, such engineers make progress in their

careers in due time, like completing probation periods and achieving better positions in the workplace.

Broadening Career Opportunities

This study supports the previous research that career opportunities for ECEs increase when they have new skills and knowledge; while actively pursuing better career paths, they can explore new areas of the engineering field. Our findings emphasise the role of LLL in assisting the engineer to acquire the necessary skills. Such LLL practices can be particularly useful for individuals who want to switch careers or pursue new opportunities within their current organisation.

"I took a course on digital marketing recently; now I can try new roles in my company." - ECE15
"Engineers with extra skills get more chances to work on big projects." - HR3
"Learning new skills opens up more job options for our engineers." - M19

The HRs and managers add that ECEs with a computer engineering background may pursue a career in digital marketing after taking courses on and developing skills in this area. Their contribution to a wider range of projects and dealing with projects that demand an understanding of the intersectionality of different expertise broadens their career opportunities by establishing their value as significant contributors to the industry.

Improving Problem-Solving Skills

Existing literature suggests that LLL helps to improve other competencies during the learning process (Stef & Mirea, 2021; Škrinjarić, 2022; Sofiadin, 2022; Lang, 2023). This study highlights that ECEs benefit significantly from practicing LLL, specifically in terms of problem solving, which is one of the key competencies sought by HRs and managers in ECEs. The results show that LLL provides ECEs with the opportunity to improve their problem-solving skills by exposing them to new challenges and equipping them with the tools and techniques necessary to address these challenges. For instance, an individual who is learning about new software development tools may be tasked with developing a new software application. Such opportunities give ECEs the chance to use their problem-solving abilities to create a solution that satisfies the industry requirements. ECES, HRs, and managers agree that LLL affects problem-solving skills positively in this context. A simple assumption is that LLL may also act as a supporting skill to strengthen other skills in cases where there is an interaction among various competencies.

"Learning new software helps me solve coding problems faster at work." - ECE47
"Problem-solving skills from learning make engineers stand out in our teams." - HR12
"Engineers who learn to solve problems improve our project results." - M6

4.5.2 Workplace Learning Barriers

According to various researchers, time constraints, lack of confidence and motivation, and rapidly changing relevance of skills are some of the challenges for LLL in the workplace (Aleksić et al., 2022; Chakrabarti et al., 2021; O'Neill et al., 2015; Illeris, 2003). The debates and issues are associated with its implementation at the employee levels (such as approachability).

The LLL challenges in the industry (Naimpally et al., 2012) are addressed from the perspective of ECEs, HRs, and managers. Additionally, the ways to overcome the challenges are addressed using the expert opinions from the senior stakeholders.

Overcoming Lack of Confidence and Motivation

"I feel I don't know enough, but feedback from my team helps me keep going." - ECE28

One finding that initially seems to be slightly offish is that 90% of the ECEs feel as if they do not know enough or are not good enough, though they do not have enough evidence to establish this point. Overcoming this understanding or feeling of lacking seems difficult, but they find it important to recognise their strengths. The challenge of keeping pace with the state-of-the-art sophistication becomes difficult to handle when engineers progress (get a better role) in their careers. At times, relentless efforts leading to burnout adversely affect the holistic development of the industry as well (Van Den Broeck et al., 2022). Breaking up tasks into smaller segments, staying organised, connecting the tasks with the purposes, and at times seeking comfort zones by reaching out to others for feedback, collaboration, and advice seem to work well.
All the ECEs and HRs, and managers agree that to be abreast of the latest updates, advancements, new tools, and frameworks seems challenging, as it requires nonstop, at times, even enervating learning and development. Rewards, awards, appreciations, and promotions strongly act as catalysts.

Time Management for Work-life Balance

"I often learn during my cab ride to save time; it's tough but helps the work." - ECE39

LLL extends office hours. Most of the ECEs find it strenuous to carve out time for learning and development. Investing extra time affects work-life balance. Learning new technologies or skills is time-consuming and effort-driven. Task deadlines are to be balanced with their learning. This can be particularly difficult when project deadlines draw near or clash with a routine but heavy workload. In 85% of HRs and managers' opinions, most of the ECEs initially fail to balance work-life. In the later stages, optimum use of LLL practices helps them to manage the workload. Many respondents, for instance, make use of their transportation time to the company for learning. Such intervals do not clash with official tasks. Task prioritisation, time gap identification and utilisation, etc., help them in easing tension, improving performance, and achieving results (Dawe et al., 2021). According to ECEs, spending quality time with the family has a positive impact on mental health and productivity.

Maintaining Skills Relevance

LLL in the industry faces an ongoing challenge of maintaining relevant skills. 90% of the ECEs feel that they need continual evaluation and assessment of their skills to remain relevant in a rapidly evolving industry, but most of them find it difficult to determine which skills are currently in demand and which areas to focus on.

"...and it's hard to know which skills matter, but programs and networking help me stay updated."- ECE44

With technology advancing at a rapid pace and the demands of the field constantly evolving, ECEs feel the need to continuously upskill and adapt. The rapid pace of technological advancements and evolving job market demands can pose challenges in ensuring the relevance and currency of the acquired skills (O'Neill et al., 2015). Keeping up with industry trends, embracing emerging technologies, and engaging in continuous learning are some of the essential LLL strategies that help engineers maintain knowledge and skills relevant.

Attending workshops, pursuing advanced certifications, participating in professional development programs, and networking with industry peers are ways to stay abreast of the latest advancements. Additionally, cultivating a growth mindset and seeking opportunities for hands-on experience can help engineers remain competitive and productive. The ability to adapt and evolve is crucial for success in this highly competitive industry. 80% of the HRs and managers agree that, though lots of efforts are made, managing the relevant skills still remains one of the most challenging issues.

Learning from Peers and Mentors

Existing research shows that mentoring and coaching are a necessity (Sofiadin, 2022; Yap & Tan, 2022) in the workplace, especially for new employees. This study also supports the argument that learning from more experienced engineers can be incredibly valuable, but what remains a challenge is finding mentors or peers who have the necessary expertise and time to provide guidance and support.

"...talking to seniors is helpful, but sometimes they're too busy to guide me." - ECE26

With reference to discussing problems with seniors and mentors in the engineering industry, ECEs feel that unapproachability can be a significant issue. The challenge can get further intricate. Firstly, the hierarchical structure of organisations may create a perception of inaccessibility, making it difficult for ECEs to approach higher-ranking seniors. Secondly, a lack of open communication channels or a culture that discourages voicing concerns can deter individuals from seeking guidance. On the other hand, HRs and managers feel that time constraints and busy schedules may limit the availability of seniors and mentors, further hindering open discussions. Overcoming these barriers requires fostering a supportive environment, promoting open-door policies, organising mentoring programs, and encouraging regular interactions to ensure that ECEs feel comfortable and supported while seeking guidance from their experienced colleagues.

4.5.3 Professional Impact

Outreach of LLL in the industry is vast and happens at personal, workplace, and societal levels.

Improved Peer Groups and Networks

The results support that learning and output-oriented collaborations and experiences smoothen career advancement of the ECEs (Aleksić et al., 2022). These interactive exchanges of knowledge, experiences, queries, and challenges expose all the stakeholders to diversified viewpoints, creative ways out, and adaptive solutions to meet the demands of the workplace. This networking helps not only individuals but also industries. Our study adds that networking may take place outside as well as inside the industry. Our results also add to the existing knowledge that ECEs learn to represent their industry, assess the knowledge gained, and understand the functioning of events through LLL. The ECEs acknowledged that they get the opportunity to identify the skill set needed. The other learning that they appreciated was that they learnt not only what to do but also what not to do on the shopfloor.

"Team discussions and other events help engineers grow and share knowledge." - M4

Networking becomes prolific and versatile when ECEs are established in a specific role at a company. Then, they make conscious efforts to connect with similar minds through conferences, team discussions, and training sessions, at times, through digital platforms. Managers agree that the next big step for the ECEs is getting affiliated with a professional body. However, the rate of enrolment in such bodies is low for the ECEs but high for managers. ECEs, managers, and HRs agree that peer grouping and networking benefit both the organisation and the ECEs.

Sustainable Careers

"...those who learn regularly stay in demand and build long careers." - HR16

Although there is research supporting the argument that LLL could help engineers secure better job roles (Yap & Tan, 2022; Aleksić et al., 2022; Chakrabarti et al., 2021), sustaining it in industry for a longer duration is challenging. This study revealed the experiences of ECEs who think that they could sustain their careers with better job performance, a competitive edge, and a continuous learning curve marked by enhanced skills and knowledge. Engineers agree that when they get opportunities for ongoing learning and development, they are more likely to feel engaged and satisfied with their work and look forward to their careers. Regarding their engagements with the current changes, they appear to be experiencing a roller coaster ride in tandem with these changes. HRs and managers add that LLL habits, such as learning new skills and technologies, can help engineers bring new ideas and approaches to their work, promoting innovation within the organisation and in the industry. Career sustainability is all about long-term sustenance, success, and satisfaction based on the use of resources, optimised utilisation of skillset, and timely availing of opportunities in a self-directed manner.

Efficient Workplaces

Our findings match the existing literature that better LLL practices contribute to efficient workplaces (Škrinjarić, 2022; Sofiadin, 2022; Chakrabarti et al., 2021). This study seeks to answer how such efficiency is achieved and also examines the role of LLL in the process. LLL reduces the time and resources required to address the tasks, which can optimise the performance of the engineer at the individual level and within teams. HRs and managers prefer engineers who

value continuous learning and development and who create an environment that fosters growth and innovation. They promote efficiency, which is achieved by ensuring a highly skilled workforce capable of adapting to changing demands, who grab opportunities to fine-tune their skills, garner novel knowledge, and be aware of current industry trends. Managers add that when organisations prioritise LLL and provide opportunities for their employees to develop new skills and knowledge, they can create a culture of learning that benefits everyone, including the organisation.

"*Learning new skills makes our workplace more productive, benefits the team as well as the individual…*" *- M13*

Data points out that an efficient workplace provides learning opportunities, working, reflecting, and implementing revised and updated knowledge to deal with issues in the specific work setting. On a complementary note, workplaces become efficient when ECEs bring in productive work output with optimal use of resources, manpower, money, and time.

Addressing Social Needs

"*...our engineers' learning helps create tech that benefits society.*" *- HR4*

This study reveals that lifelong learners in the industry play a crucial role in shaping the technology landscape and addressing societal needs through their continuous learning and application of engineering skills. Better LLL practices ensure accessibility, adaptability, and inclusive digitalization of society. Managers highlight that LLL practices help engineers in identifying and optimising/solving problems that exist in society by observing and understanding what society wants (Engineering Skills for the Future, 2019). ECEs provided the example of fast adoption of United Payment Interface (UPI) applications, which facilitated fast and secure digital payments and banking for society. LLL opens new avenues for ECEs to change their career paths. This flexibility establishes their credibility as desirable and significantly valuable within the societal context.

5. Recommendations

5.1 Recommendations to the ECEs

ECEs should engage in lifelong learning to keep up with the most recent trends and technologies. ECEs should be adaptable to any situation to learn and collaborate with any team role and environment. ECEs should use their foresight to understand and deal with problems. The other important points of recommendation are rightfully addressed by the feedback received from one of the experts from the industry:

"*Don't be afraid to ask questions. No one expects you to know everything right away. If you don't understand something, ask your supervisor or a more experienced engineer for help. Don't be afraid to make mistakes. Everyone makes mistakes, especially when they're new. The important thing is to learn from your mistakes and not make the same ones twice. Be patient. It takes time to learn and grow as an engineer. Don't expect to be an expert overnight. Enjoy the journey.*

Engineering is a challenging and rewarding field. Soak up every experience and learn as much as you can."

5.2 Recommendations to the Policy Makers and Academia

Policy makers may introduce industry participation in universities to align education with industry needs. The 'taste' of the industry would make the students confident and ready to be an engineer. This stage of the shift is very important for their career in terms of future prospects with ill-defined issues. Project-based courses that integrate industry experiences with academic knowledge may be drafted after consulting with the industry representatives. Academia and industry may have a single point of contact for such initiatives.

Academia should make students aware of industry-focused engineering collaborations, conferences, etc. Industry-based case studies may be referred to orient students to familiarise them with the industry perspective. Courses directly focusing on transversal competencies may be introduced in the curriculum to help the students understand the working of tasks.

6. Conclusion

LLL is one of the key competencies to provide a smooth transition as well as a firm foundation to ECEs in the workplace. LLL emphasises the centrality of learning, shifting the traditional rigidity to the state of fluidity/free flowing, where ECEs can learn constructively in consonance with their individual needs and interests. LLL helps ECEs gel well with the world of work, groom themselves personally and professionally, and improve their quality of life. LLL theories traditionally focus on aspects like types, sources, workplace practices, etc. There is scant focus on internal and external workplace needs and obligations. This research adds one more layer to the existing knowledge on LLL by reflecting the differences between personal and workplace learning practices and various effects of LLL as a driver for sustainable engineering careers. ECEs' career sustainability is conditioned by their skills, mindset, and adaptability needed to thrive in a rapidly evolving professional landscape. A holistic approach enhances ECEs' ability to navigate career challenges, embrace innovation, and contribute meaningfully to sustainable and impactful engineering practices. Better LLL practices in the industry not only result in the optimised functioning in the workplace, leading to better economic outcomes, but also groom the ECEs to thrive and sustain their careers. Policy makers, accreditation agencies, and industries may focus more on such research where the opinions and experiences of the ECEs, their HRs, and managers are reflected. These direct inputs from the industries would help to reduce the transition time taken for shaping engineering graduates as sustainable engineering professionals.

7. Limitations and Future Directions

This study, while rooted in its constructivist GT approach, is constrained by its focus on a single work domain (engineering in Indian MNCs) and data from three stakeholder groups (ECEs, HRs, managers) across four engineering industries, ensuring reliability and validity through diverse perspectives. To address this limitation, future research could aim to: quantitatively assess the measurable outcomes of LLL, such as its impact on employability metrics (e.g., promotion rates, skill acquisition efficiency), to complement the qualitative insights of the current dynamics; and

extend the sustainability dynamics to other industries to evaluate its applicability and refine TVC development across diverse professional contexts, enhancing the model's generalizability and practical utility.

References

Aggarwal, R., & Wu, Y. (2019). Challenges in Implementing Experiential Learning in IB Education. *Journal of Teaching in International Business*, *30*(1), 1–5. *https://doi.org/10.1080/08975930.2019.1637807*

Al., J. J. E. (2012). *Gauging Workplace Readiness: Assessing the Information Needs of Engineering Co-op Students*. Issues in Science and Technology Librarianship. *https://doi.org/10.5062/F4X34VDR*

Aleksić, A., Nestić, S., Huber, M., & Ljepava, N. (2022). The Assessment of the Key Competences for Lifelong Learning—The Fuzzy Model Approach for Sustainable Education. *Sustainability*, *14*(5), 2686. *https://doi.org/10.3390/su14052686*

Allen, S. J., Rosch, D. M., & Riggio, R. E. (2022). Advancing Leadership Education and Development: Integrating Adult Learning Theory. *Journal of Management Education*, *46*(2), 252–283. *https://doi.org/10.1177/10525629211008645*

Aspin, D. N., & Chapman, J. D. (2007). Lifelong Learning: Concepts and Conceptions. In D. N. Aspin (Ed.), *Philosophical Perspectives on Lifelong Learning* (Vol. 11, pp. 19–38). Springer Netherlands. *https://doi.org/10.1007/978-1-4020-6193-6_1*

Atchoarena, D. (with UNESCO & International Bureau of Education). (2022). *Making lifelong learning a reality: A handbook*. UNESCO Institute for Lifelong Learning.

Austin, M., & Rust, D. Z. (2015). Developing an Experiential Learning Program: Milestones and Challenges. *The International Journal of Teaching and Learning in Higher Education*, *27*, 143–153.

Candy, P. (1992). Self-Direction for Lifelong Learning. *Adult Education Quarterly*, *42*(3), 192–193. *https://doi.org/10.1177/074171369204200307*

Chakrabarti, S., Caratozzolo, P., Norgaard, B., & Sjoer, E. (2021). Preparing Engineers for Lifelong Learning in the Era of Industry 4.0. *2021 World Engineering Education Forum/Global Engineering Deans Council (WEEF/GEDC)*, 518–523. *https://doi.org/10.1109/WEEF/GEDC53299.2021.9657247*

Charmaz, K. (2025). *Constructing grounded theory* (Third edition). Sage.

Corbin, J., & Strauss, A. (2015). *Basics of Qualitative Research (3rd ed.): Techniques and Procedures for Developing Grounded Theory*. SAGE Publications, Inc. *https://doi.org/10.4135/9781452230153*

Cruz, M. L., Saunders-Smits, G. N., & Groen, P. (2020). Evaluation of competency methods in engineering education: A systematic review. *European Journal of Engineering Education*, *45*(5), 729–757. *https://doi.org/10.1080/03043797.2019.1671810*

Cummins, P., & Kunkel, S. (2015). A Global Examination of Policies and Practices for Lifelong Learning. *New Horizons in Adult Education and Human Resource Development*, *27*(3), 3–17. *https://doi.org/10.1002/nha3.20107*

Dawe, N., Romkey, L., Bilton, A., & Khan, R. (2021). A Review of How Lifelong Learning Is Planned and Enacted in Canadian Engineering Programs. *Proceedings of the Canadian Engineering Education Association (CEEA)*. *https://doi.org/10.24908/pceea.vi0.14950*

Delors, J., & Unesco (Eds.). (1996). International Commission on Education for the Twenty-first Century, *Learning, the treasure within: Report to UNESCO of the International Commission on Education for the Twenty-first Century*. Unesco Pub.

Government Office for Science. (2017). *Future of Skills & Lifelong Learning*. *https://assets.publishing.service.gov.uk/media/5b51fbdae5274a3fd124c916/Foresight-future-of-skills-lifelong-learning_V8.pdf*

Hase, S., & Kenyon, C. (2000). From Andragogy to Heutagogy. Ultibase Articles, 5, 1-10.

Hedin, N. (2010). Experiential Learning: Theory and Challenges. *Christian Education Journal: Research on Educational Ministry*, *7*(1), 107–117. *https://doi.org/10.1177/073989131000700108*

Illeris, K. (2003). Workplace learning and learning theory. *Journal of Workplace Learning*, *15*(4), 167–178. *https://doi.org/10.1108/13665620310474615*

Ismaili, B., Bakkali, S., & Benriyene, S. (2025). The Employability of Engineers in the Era of Industry 4.0. *The 1st International Conference on Smart Management in Industrial and Logistics Engineering (SMILE 2025)*, 35. https://doi.org/10.3390/engproc2025097035

Jackson, D., Shan, H., & Meek, S. (2022). Employer development of professional capabilities among early career workers and implications for the design of work-based learning. *The International Journal of Management Education*, *20*(3), 100692. *https://doi.org/10.1016/j.ijme.2022.100692*

Jeffryes, J., & Lafferty, M. (2012). Gauging Workplace Readiness: Assessing the Information Needs of Engineering Co-op Students. *Issues in Science and Technology Librarianship*, *69*. *https://doi.org/10.29173/istl1548*

Johri, A., & Olds, B. M. (2011). Situated Engineering Learning: Bridging Engineering Education Research and the Learning Sciences. *Journal of Engineering Education*, *100*(1), 151–185. https://doi.org/10.1002/j.2168-9830.2011.tb00007.x

Kirby, J. R., Knapper, C., Lamon, P., & Egnatoff, W. J. (2010). Development of a scale to measure lifelong learning. *International Journal of Lifelong Education*, *29*(3), 291–302. *https://doi.org/10.1080/02601371003700584*

Knowles, M. S. (1980). *The modern practice of adult education: From pedagogy to andragogy* (Rev. and updated). Cambridge Adult Education.

Kolb, A. Y., & Kolb, D. A. (2017). *The experiential educator: Principles and practices of experiential learning*. EBLS Press.

Laal, M., & Salamati, P. (2012). Lifelong learning; why do we need it? *Procedia - Social and Behavioral Sciences*, *31*, 399–403. *https://doi.org/10.1016/j.sbspro.2011.12.073*

Lang, J. (2023). Workforce upskilling: Can universities meet the challenges of lifelong learning? *The International Journal of Information and Learning Technology*, *40*(5), 388–400. *https://doi.org/10.1108/IJILT-01-2023-0001*

Ladesic, J. G., Wolz, R. R., Simmons, F., III, & Farley, T. D. (2012). A college-industry partnership: The multidisciplinary master's of science in engineering. In *Proceedings of the 119th ASEE Annual Conference*. San Antonio, TX.

Lifelong Learning | EUR-Lex. (2025). Europa.eu. *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=legissum:c11047*

Lombardo, M. M., & Eichinger, R. W. (2006). *The career architect development planner: An expert system offering 103 research-based and experience-tested development plans and*

coaching tips for learners, managers, mentors and feedback givers (4. ed). Lominger Limited.

Mahoney, M. H. (2017). An Academic Librarian's Search for Meaning: A Survey of Lifelong Learning in Library Literature. *The Journal of Academic Librarianship*, *43*(6), 540–547. https://doi.org/10.1016/j.acalib.2017.05.004

Martinez-Mediano, C., & Lord, S. M. (2012). Lifelong Learning Program for engineering students. *Proceedings of the 2012 IEEE Global Engineering Education Conference (EDUCON)*, 1–6. https://doi.org/10.1109/EDUCON.2012.6201072

Mlambo, M., Silén, C., & McGrath, C. (2021). Lifelong learning and nurses' continuing professional development, a metasynthesis of the literature. *BMC Nursing*, *20*(1), 62. https://doi.org/10.1186/s12912-021-00579-2

Naimpally, A. V., Ramachandran, H., & Smith, C. (2012). *Lifelong learning for engineers and scientists in the information age* (1st ed). Elsevier. Narayanan, S. C., Emad, G. R., & Fei, J. (2023). Theorizing seafarers' participation and learning in an evolving maritime workplace: An activity theory perspective. *WMU Journal of Maritime Affairs*, *22*(2), 165–180. https://doi.org/10.1007/s13437-023-00311-8

Nimmi, P. M., Zakkariya, K. A., & Rahul, P. R. (2021). Channelling employability perceptions through lifelong learning: An empirical investigation. *Education + Training*, *63*(5), 763–776. https://doi.org/10.1108/ET-10-2020-0295

Park, J.-Y., & Kim, J.-M. (2023). A Qualitative Study on the Informal Learning of Manufacturing Engineers. *Korean Association For Learner-Centered Curriculum And Instruction*, *23*(16), 789–808. https://doi.org/10.22251/jlcci.2023.23.16.789

OECD. (2010). *Learning for Jobs*. OECD. https://doi.org/10.1787/9789264087460-en

O'Neill, T. A., Deacon, A., Larson, N. L., Hoffart, G. C., Brennan, R. W., Eggermont, M., & Rosehart, W. (2015). Life-long learning, conscientious disposition, and longitudinal measures of academic engagement in engineering design teamwork. *Learning and Individual Differences*, *39*, 124–131. https://doi.org/10.1016/j.lindif.2015.03.022

Saldaña, J. (2013). *The coding manual for qualitative researchers* (2. ed). SAGE Publ.

Sangwan, D., & Venugopal, A. (2022). Essentiality of knowing transversal competencies: Towards engineering education sustainability and industry readiness of engineering students. *Towards a New Future in Engineering Education, New Scenarios That European Alliances of Tech* Universities *Open Up*, 663–671. https://doi.org/10.5821/conference-9788412322262.1347

Savickas, M. L. (2013). Career Construction Theory and Practice. In S. D. Brown, & R. W. Lent, *Career Development and Counseling: Putting Theory and Research to Work* (2nd ed., pp. 147-183). John Wiley & Sons.

Seniuk Cicek, J., Ingram, S., & Friesen, M. (2016). On Becoming an Engineer: The Essential Role of Lifelong Learning Competencies. *2016 ASEE Annual Conference & Exposition Proceedings*, 27331. https://doi.org/10.18260/p.27331

Škrinjarić, B. (2022). Competence-based approaches in organizational and individual context. *Humanities and Social Sciences Communications*, *9*(1), 28. https://doi.org/10.1057/s41599-022-01047-1

Sofiadin, A. (2022). Education 4.0, Industry 4.0, Lifelong Learning: A Descriptive Literature Review. *International Journal of Research Publications*, *113*(1). https://doi.org/10.47119/IJRP10011311120214132

Stef, D., & Mirea, N. (2022). *ACTA Technica Napocensis Lifelong Learning in Context of Industry 4.0*. *64*, 55–61.

Vailasseri, P., Long, J. M., & Joordens, M. (2021). Embedding Bachelor of Engineering University Education with Enhanced Work-Integrated Learning. *Education Sciences*, *11*(11), 756. *https://doi.org/10.3390/educsci11110756*

Van Den Broeck, L., Craps, S., Beagon, U., Naukkarinen, J., & Langie, G. (2022). Lifelong learning as an explicit part of engineering programmes: What can we do as educators? *Towards a New Future in Engineering Education, New Scenarios That European Alliances of Tech Universities Open Up*, 774–781. *https://doi.org/10.5821/conference-9788412322262.1327*

Walters, D. (2021). The mind, the heart and the joule in the crown: A holistic approach to lifelong learning. *Thinking Skills and Creativity*, *39*, 100755. *https://doi.org/10.1016/j.tsc.2020.100755*

Wetzel, A. P., Mazmanian, P. E., Hojat, M., Kreutzer, K. O., Carrico, R. J., Carr, C., Veloski, J., & Rafiq, A. (2010). Measuring Medical Students' Orientation Toward Lifelong Learning: A Psychometric Evaluation: *Academic Medicine*, *85*, S41–S44. *https://doi.org/10.1097/ACM.0b013e3181ed1ae9*

Wheebox, All India Council for Technical Education (AICTE), Confederation of Indian Industry (CII), & Association of Indian Universities (AIU). (2023). *India Skills Report 2024: Impact of AI on the future of work, skilling & mobility*. Wheebox. *https://wheebox.com/assets/pdf/ISR_Report_2024.pdf*

Yap, J. S., & Tan, J. (2022). Lifelong learning competencies among chemical engineering students at Monash University Malaysia during the COVID-19 pandemic. *Education for Chemical Engineers*, *38*, 60–69. *https://doi.org/10.1016/j.ece.2021.10.004*

Zhang, Y. L., Bai, L. Z., & Zhang, D. (2010). Strengthening the Engineer's Lifelong Education. *Advanced Materials Research*, *156–157*, 241–244. *https://doi.org/10.4028/www.scientific.net/AMR.156-157.241*

Zimmerman, B. J. (2008). Investigating Self-Regulation and Motivation: Historical Background, Methodological Developments, and Future Prospects. *American Educational Research Journal*, *45*(1), 166–183. *https://doi.org/10.3102/0002831207312909*

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