Updating the Professional Knowledge of Electronics Engineers in the Context of Rapidly Changing Technologies

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Abstract

Rapid technological advancement driven by Industry 4.0 and the emerging Industry 5.0 paradigm is fundamentally transforming the professional landscape of electronics engineering. The increasing integration of cyber-physical systems, artificial intelligence, cloud computing, big data analytics, and intelligent automation requires engineers to continuously update both technical and transversal competencies. This paper analyzes the impact of technological transformation on the professional skill profile of electronics engineers and identifies existing gaps between higher education outcomes and labor market expectations. Attention is given to the balance between hard skills – such as programming, embedded systems design, and digital system integration – and soft skills, including critical thinking, adaptability, collaboration, and problem-solving. The study synthesizes contemporary research findings and highlights the importance of competency-based education, project-based and problem-based learning, virtual laboratories, and industry-academia collaboration as effective mechanisms for renewal of professional knowledge. The results emphasize that lifelong learning, systematic upskilling and reskilling strategies, and the integration of innovative educational technologies are essential to ensure the adaptability, sustainability awareness, and competitiveness of electronics engineers in rapidly evolving industrial environments.

Keywords

Electronics engineering; Industry 4.0; Industry 5.0; professional competencies; lifelong learning; upskilling and reskilling; competency-based education; virtual laboratories; engineering education; digital transformation

1. Introduction

The Fourth Industrial Revolution has introduced new challenges for the workforce, as emerging technologies require new skills and competencies. Technologies such as the Industrial Internet of Things (IoT), cloud computing, big data, simulation, 3D reality, additive manufacturing (3D printing), horizontal and vertical system integration, autonomous robots, cybersecurity, and cyber-physical systems form the technological foundation of the Fourth Industrial Revolution. These technologies enable the interconnection of devices, systems, and data, ensuring advanced, digitalized, and automated industrial operations [1]. It is projected that, given the current pace of technological development, as many as 44% of workers' skills will need to fundamentally change [2].

Demand in the labor market is expected to increase for specialists with competencies in software development, information technology, and information and communication technologies due to the growing use of digital technologies and data analytics. Skills such as adaptability, creativity, and problem-solving will also become increasingly important [1, 3]. Emerging technologies significantly influence electronics engineering by optimizing systems and advancing both hardware and software development [4, 5]. Please check Table 1 which presents specific technologies, trends, and changes associated with the Fourth Industrial Revolution that impacted the field of electronics engineering.

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Table 1
Technologies Influencing the Profession of Electronics Engineering (based on [6])

Technology	Influence on electronics engineering
Internet of Things (IoT)	Involves interconnected devices and sensor networks enabling continuous data exchange. Electronics engineers develop and optimize communication architectures ensuring interoperability, reliability, and efficiency.
Robotics	Requires advanced control, sensing, and power systems. Electronics engineers design and improve embedded and automation systems supporting robotic applications.
Virtual Reality (VR) and Artificial Intelligence (AI)	Demand specialized hardware and intelligent processing systems. Electronics engineers contribute to the development of computational platforms and integrated electronic solutions enabling these technologies.
Cloud Technology	Enables distributed data storage and remote system integration. Electronics engineers contribute to the development of infrastructure and support electronic systems for cloud-based environments.
Blockchain Technology	Introduces decentralized and secure data management models requiring reliable electronic and communication systems designed by Electronics engineers.

As presented in Table 1, technologies will continue to evolve, and the role of electronics engineers in innovation within these domains will further expand. Continuous learning and skills upgrading will therefore be essential for electronics engineers to adapt to ongoing changes [6].

Engineering education is also essential for promoting global sustainability by developing and implementing sustainable technologies and technological innovations. It thus plays a crucial role in realizing the principles of the Fifth Industrial Revolution. This revolution differs from previous ones by placing particular emphasis on the application of research and innovation to ensure that industry serves humanity in the long term while respecting planetary sustainability limits. Engineering professionals and their knowledge are vital for achieving sustainable development, especially in implementing sustainable technologies and new systems [7].

Moreover, the Fifth Industrial Revolution emphasizes collaboration between humans and intelligent machines through advanced digital technologies such as cognitive artificial intelligence, adaptive robotics, digital twins, blockchain, the Internet of Everything (IoE), and 6G networks. Future engineers must not only be able to use these technologies but also anticipate their impact, assess cybersecurity risks, and ensure data security [8].

The core problem addressed in this paper is the "content overload" and the lack of personalized, time-efficient educational pathways that align with the intense schedules of electronics engineers. Despite the strategic importance of the field, empirical data on specific learner needs and barriers remains scarce.

The aim of the study presented in this paper is to identify the professional development priorities of electronics engineers and propose a framework for a virtual learning environment (VLE). By analyzing survey data from 19 industry specialists, this research highlights the necessity of integrating AI-based personalization and virtual laboratories into modern training systems to ensure sustainable competency growth.

2. Necessity for updating professional knowledge

Modern education systems combine the advantages of classical and digital learning, providing students with foundational and specialized preparation for employment, as well as competencies for the practical application of theoretical knowledge across various industrial roles [9]. However, a skills mismatch arises due to the gap between competencies developed in higher education and industry expectations, and the emergence of Industry 4.0 has further intensified the need for advanced, technology-aligned skills [10].

For example, employees in the renewable energy sector must possess digital competencies, demonstrate adaptability to rapid change, continuously upgrade their qualifications, and implement

new systems and processes [11]. Future labor markets will be increasingly automated and dynamic, enhancing the value of skills that enable workers to collaborate effectively with machines, master emerging digital technologies, and adapt to ongoing transformation. The transition toward high-skilled professions will require substantial upskilling and reskilling of the workforce [12].

Current labor market trends and increased employer demand for professionals with competencies aligned with modern technological standards necessitate the preparation of competitive specialists [13]. For instance, the microelectronics sector is experiencing a growing workforce shortage, which may be mitigated by attracting young talent and retraining the existing workforce [14]. Nevertheless, despite increasing attention to these issues, organizations face difficulties in effectively implementing qualification strategies. Traditional training often fails to keep pace with technological change, leading to skills mismatches, while the absence of an integrated approach results in short-term initiatives [15].

Employability skills encompass the knowledge, abilities, and competencies required to obtain and maintain employment and to adapt to change. Higher education attainment, teamwork skills, ICT competencies, problem-solving abilities, and communication skills facilitate employment and career progression [16]. A study by Ismail and Hassan showed that the level of knowledge and skills among electronics engineers is moderate and insufficiently aligned with emerging technologies, highlighting the need to update curricula [17]. Competency gaps are also associated with higher unemployment rates, often considered a failure of the education system to prepare competitive graduates who meet labor market needs [18].

Competencies are considered the basis for skill standards that define the level of knowledge required for successful performance in the workplace, as well as criteria for assessing competency achievement. Skills, in contrast, refer to an individual's ability to apply knowledge and techniques to perform tasks and solve problems [19]. According to the International Standard Classification of Occupations (ISCO), competencies characteristic of electronics engineers includes designing electronic systems, approving engineering projects, using technical drawing software, establishing testing procedures for electronic equipment, preparing technical reports, and developing technical plans [20].

Contemporary technologies also generate demand for the development of the following skills:

- **Personal skills**: adaptability, tolerance for ambiguity, motivation for learning, ability to work under pressure, and sustainable thinking;
- **Social / interpersonal skills**: intercultural competence, language proficiency, communication skills, networking skills, teamwork, knowledge transfer abilities, and leadership;
- **Technical skills**: technical expertise, media literacy, and programming skills;
- **Methodological skills**: creativity, research skills, problem-solving, conflict resolution, and decision-making [21, 22, 23].

Electronics engineers must possess systems thinking skills and commitment to lifelong learning to adapt to continuous technological advancement [24]. Continuous professional training plays a crucial role in engaging and motivating engineers to enhance their skills and qualifications through practical activities, emphasizing problem-solving based on emerging technological knowledge and competencies [25].

Skills are commonly categorized as:

- **Soft skills**, which include knowledge, abilities, and qualities relevant to everyday and professional life;
- **Hard skills**, also known as technical skills, are related to the understanding and management of professional activities through the application of methods, processes, and technical expertise [26].

Research indicates that electronics specialists lack both soft and hard skills. Academics emphasize discipline and responsibility, whereas industry prioritizes teamwork and analytical thinking. In terms of hard skills, academics highlight ICT literacy, while industry stresses organizational abilities and troubleshooting skills [27]. The most in-demand soft skills for the future include reliability and self-discipline, creativity and originality, critical thinking and analysis, reasoning and problem-solving, as well as resilience and adaptability [28].

However, engineering curricula typically prioritize hard *(technical)* skills over soft skills development [29, 30]. The majority of engineering education content remains technically oriented, underscoring the need to emphasize and systematically integrate soft skills training [31]. Soft skills are essential because they complement technical competencies, foster independent learning, encourage critical thinking, and support adaptability in an ever-changing engineering environment [32].

In conclusion, electronics engineers face deficiencies in both hard and soft skills, while existing study programs often focus predominantly on technical aspects. Contemporary technologies require continuous knowledge updating, critical and creative thinking, problem-solving abilities, teamwork, and digital competencies; therefore, integrating professional knowledge and skills development into engineering education is essential.

3. Empirical study of professional development needs of electronics engineers

The accelerating pace of technological change requires a data-driven approach to understanding the educational gaps in the electronics engineering sector. This section presents the findings of a pilot study to identify the specific requirements for a modern VLE for the professional development of electronics engineers.

3.1. Methodology and participant profile

The study was conducted using a dual-stage approach: a broad survey of industry specialists followed by a focused case study within a high-tech engineering enterprise. The primary instrument was a structured questionnaire focusing on three dimensions: professional profile, learning preferences, and technological barriers.

The sample (n=19) consisted of a highly experienced workforce, with 50% of participants belonging to the 46–55 age group. The professional distribution was significantly tilted towards leadership and expertise: 38.89% were senior specialists and 38.89% held managerial positions. The participants primarily represented small and medium-sized enterprises (SMEs) (94.4%), with the majority active in electronic systems design (44.44%) and manufacturing (38.89%). This profile ensures that the gathered data reflects the needs of decision-makers and high-level technical experts.

3.2. Detailed analysis of upskilling preferences

The empirical results highlight a decisive shift towards digital and flexible learning methods:

- **Learning Formats**. Distance learning was identified as the preferred form by 61.11% of respondents, followed by blended learning (22.22%). The data shows that traditional, strictly classroom-based methods were strongly rejected (only 16.67% of respondents preferred such methods).
- **Methodological Requirements**. A vast majority (88.89%) identified online courses combined with practical tasks and instructor consultations as the most effective method for qualification improvement. This indicates that passive video lectures are insufficient; interactive, practice-oriented modules are required.
- **Technological Tools**. While general-purpose tools like MS Teams / Zoom are widely used (88.89%), there is a significant baseline interest in specialized educational technology. 55.56% of respondents prefer Learning Management Systems (e.g., Moodle), and 27.78% emphasized the need for virtual labs to simulate physical engineering processes.
- **Platform Usage**. The study shows that engineers are already utilizing global platforms: 72.22% of respondents use Coursera and 55.55% use LinkedIn Learning. This shows that the new virtual environment must match the user experience and quality of these global leaders.

3.3. Identified barriers and content priorities

Understanding the obstacles to learning is crucial for designing effective interventions. The study revealed:

- **Time Constraints**. The most critical barrier is lack of time. Most engineers (50%) able to dedicate time to learning only a few times per week. The preferred course duration is relatively short. 50% of respondents favor courses under 40 hours.
- **Subject Matter**. The most urgent technical topics identified include **Microcontroller Programming (44.44%)** and modern engineering methodologies (33.33%).
- **"Content Overload" and Support**. In the second phase of the study, 100% of respondents indicated a high need for skill development, but every participant noted that current courses often contain too much redundant material. 83.33% of respondents expressed a need for a **virtual assistant** or mentor to help navigate the learning process and provide individualized feedback.

3.4. Summary of findings

The study revealed the main learning priorities and barriers for electronics engineers. Please check Table 2 which presents a clear overview of the study data with the summarized key indicators of learning priorities and identified barriers for electronics engineers.

Table 2
Analysis of Professional Development Needs and Obstacles (based on research results)

Category	Key Indicators	Percentage
Preferred Format	Remote learning (Online)	61.11%
Methodology	Online courses with practical tasks	88.89%
Urgent Topics	Microcontroller Programming	44.44%
	Modern engineering methods	33.33%
Major Barriers	Lack of time	50.00%
	Unavailability of relevant courses	38.89%
Preferred Duration	Short-term courses (up to 40 hours)	50.00%
Support Needs	Individual learning programs	100.00%*

*Based on the secondary enterprise-specific case study.

The data in Table 2 highlights a critical need for high-intensity, short-duration practical training. The demand for individual learning programs (indicated by 100% of respondents) further emphasizes the necessity of moving towards adaptive, AI-enhanced educational frameworks that can tailor content to the specific time constraints of the professional.

4. Methods and opportunities for updating the professional knowledge of electronics engineers

A new engineering education strategy has emerged in response to technological revolution and industrial transformation, aiming to develop highly qualified engineering professionals with interdisciplinary knowledge, innovative capabilities, practical skills, and a global perspective. This new training model involves not only deepening traditional engineering disciplines but also integrating them with advanced technologies such as information technology, artificial intelligence, and big data.

In electronics engineering, this entails updating curricula, strengthening practical preparation, and fostering innovation to prepare specialists who meet contemporary labor market demands [33]. Professional knowledge is assessed based on mastery of theoretical foundations, the level of practical skills, competence in applying professional tools, and the demonstration of innovation and creativity

throughout the study process [34]. Traditional models of training electronics technology specialists can no longer meet the demands of current socio-economic development [35].

The updating of professional knowledge in engineering is grounded in targeted educational strategies and strengthened collaboration between academia and industry:

- **Competency-based education**: focusing on clear and measurable learning outcomes and developing transferable skills that broaden career opportunities;
- **Challenge-based education**: engaging students in solving real engineering problems to strengthen practical knowledge application and reduce the gap between theory and practice;
- **Regular curriculum renewal**: integrating the latest technological trends, industry needs, and skill requirements to reduce competency mismatches in the labor market;
- **Industry–academia collaboration**: developing partnerships, joint research projects, internships, and advisory boards to better align specialist training with real sector needs;
- **Continuous industry feedback**: involving employers and experts in shaping study content and identifying current and future competency requirements [12].

Various programs are currently being implemented to assist both employees and employers in adapting to changing labor market conditions in engineering. Skills development focuses on improving competencies within one's current career path to perform existing tasks more effectively [36]. Upskilling strengthens existing competencies or develops advanced skills within a current role, enabling employees to perform more effectively while preparing for career growth. Through structured training programs, seminars, and professional development initiatives, organizations enhance employee capabilities, productivity, and motivation [15].

Training should be an integral part of lifelong professional development throughout an engineer's career [37]. Educational processes should reduce excessive theoretical instruction and place greater emphasis on project-based learning, which develops teamwork and critical engineering skills. Additionally, comprehensive online tools should be developed to promote self-directed learning, support both asynchronous and synchronous communication, and ensure that course design aligns with lifelong learning objectives.

Methods such as project-based learning, problem-based learning, and case studies can enhance student engagement, initiative, creativity, and practical abilities. The use of modern educational tools, including virtual simulation technologies and online experimental platforms, provides more accessible and effective practical learning opportunities [31]. Engineering education and continuous training play a crucial role in motivating engineers to upgrade qualifications through hands-on activities emphasizing problem-solving based on emerging technologies [25].

Research indicates that integrating advanced educational technologies and interactive learning formats within blended learning systems contributes to the formation of professional competencies in electrical engineering and electromechanics students. Simulation, virtual laboratories, and case-based methods improve understanding of energy production processes, promote efficient resource use, and address contemporary energy challenges [38].

Project-based learning is grounded in practical projects where students actively learn, collaborate in problem-solving, and apply theoretical knowledge in practice. Studies show that project-based approaches strengthen professional knowledge and practical skills among electronics engineering students. A structured system of practical training enables the gradual development of competencies and better preparation for engineering activities [39].

With the rapid digitalization of education, virtual laboratories have become a key tool for technical training, particularly in electronics and engineering. They enhance accessibility and interactivity in practical education, while modern platforms support remote collaboration [40]. Laboratory work can be effectively organized either as simulation-based laboratories or as remotely controlled physical laboratories [41]. Research demonstrates that virtual experiments are often as effective as physical ones in improving knowledge acquisition and student confidence. The use of virtual and augmented reality technologies provides engineering students with more interactive and realistic learning experiences [16].

Virtual laboratories enable students to utilize innovative technological tools and methods while collaborating in teams [42]. They also foster skills necessary for complex workplace environments involving practical tasks [43]. For example, VR-based laboratories create immersive environments that simulate real-world contexts, allowing learners to practice procedures and interact with

equipment in realistic settings. Students using VR laboratories often achieve better learning outcomes compared to those using conventional teaching methods [44, 45].

Based on the literature review and empirical findings, a **conceptual framework for a VLE** is proposed to update the professional knowledge of electronics engineers. This framework consists of three integrated layers:

1. **Adaptive Content Layer:** utilizes AI-driven skill assessment to personalize upskilling pathways, directly addressing the "content overload" and time constraints identified in the survey (50% of respondents).
2. **Interactive Simulation Layer:** incorporates virtual labs and digital twins for practical microcontroller programming and system design, fulfilling the 88.89% demand for practice-based learning. A key element of the proposed framework is the integration of **Virtual Reality (VR)** technologies to provide immersive, high-fidelity practical experience. While traditional virtual labs are often screen-based, the use of VR headsets allows engineers to enter a 3D simulated environment where they can perform complex experiments, such as circuit assembly or hardware debugging, as if they were in a physical laboratory. This immersive approach addresses the need for "hands-on" practice in a remote setting, which was highlighted by 88.89% of survey respondents. By simulating expensive equipment and hazardous environments safely, VR-based labs offer a cost-effective and scalable solution for industry-aligned training
3. **Supportive Feedback Layer:** features AI-based virtual assistants to provide real-time mentorship and reduce the isolation of remote learning. This framework shifts the educational focus from static content delivery to a dynamic, industry-aligned competency development system.

In summary, updating the professional knowledge of electronics engineers should be based on modern educational strategies, strong collaboration between academia and industry, and continuous competency development through the integration of advanced technologies and practice-oriented teaching methods. Research confirms that project-based and problem-based learning, virtual laboratories, and digital platforms significantly strengthen practical skills, innovation capacity, and preparedness for evolving labor market demands.

5. Conclusions

The study confirms that the professional development priorities of electronics engineers are focused on highly practical, short-term modules, especially in the areas of **Microcontroller Programming** and modern engineering methodologies. A significant digital readiness was identified. 61.11% of specialists prefer distance learning. However, the critical barrier remains the lack of time and the absence of high-quality, practice-oriented remote tools.

To address these challenges, the proposed **VLE framework** integrates AI-based personalization with immersive technologies. The inclusion of **VR** allows engineers to utilize hardware, such as VR headsets, to access high-fidelity laboratory simulations at home. This directly aligns with the learners' preference for distance learning while ensuring that the practical, "hands-on" nature of electronics engineering is preserved. By enabling complex experiments to be conducted outside of physical facilities, the proposed VLE framework provides a flexible, scalable, and future-ready solution for professional development of electronics engineers.

6. Declaration on Generative AI

The authors have not employed any Generative AI tools.

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