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Article

Industry Perspectives on Electrical Competencies and Artificial Intelligence Readiness for Workforce Development in the Zamboanga Peninsula, Philippines

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Abstract: The rapid advancement of Industry 4.0 has increased the demand for electrical professionals who possess both strong technical competencies and artificial intelligence (AI) readiness. This study explored industry perspectives on the electrical competencies and AI readiness required for workforce development in the Zamboanga Peninsula, Philippines. A qualitative descriptive research design was employed involving purposively selected industry stakeholders from the electrical, manufacturing, energy, utilities, and industrial sectors. Data were collected through semi-structured interviews and analyzed using reflexive thematic analysis. Six themes emerged: Technical Competence, Professional Attributes, AI Transformation, Digital Readiness, Curriculum Enhancement, and Industry Collaboration. The findings revealed that industries continue to prioritize strong engineering fundamentals while increasingly expecting graduates to develop AI literacy, digital competencies, analytical skills, and adaptability to meet evolving workforce demands. Participants likewise emphasized the importance of curriculum modernization and stronger industry-academe partnerships to ensure workforce readiness. The study underscores the need for competency-based engineering education that aligns with Industry 4.0 and emerging AI technologies.

Keywords: electrical competencies, artificial intelligence readiness, workforce development, Industry 4.0, engineering education

1. Introduction

The Fourth Industrial Revolution (Industry 4.0) has transformed industrial production through the integration of artificial intelligence (AI), automation, cyber-physical systems, the Internet of Things (IoT), cloud computing, robotics, and advanced data analytics into manufacturing and engineering processes. These technological innovations have significantly improved operational efficiency, productivity, and decision-making while simultaneously redefining workforce requirements across engineering disciplines. As industrial environments become increasingly intelligent and interconnected, organizations require professionals who possess not only strong technical competencies but also digital literacy, analytical thinking, adaptability, interdisciplinary collaboration, and lifelong learning skills to remain competitive in technology-driven workplaces (Miranda et al., 2021; Saniuk et al., 2021; Roll & Ifenthaler, 2021; Li, 2024).

Among engineering professions, the electrical sector has undergone substantial technological transformation. Conventional electrical work involving installation, maintenance, operation, and troubleshooting has expanded to include smart grids, intelligent control systems, industrial automation, robotics, predictive maintenance, machine learning, and AI-assisted diagnostics. Consequently, electrical professionals are increasingly expected to integrate traditional engineering knowledge with competencies in automation, programming, digital communication, data interpretation, cybersecurity awareness, and AI-enabled decision support. These technological developments require engineering graduates to acquire multidisciplinary competencies that enable them to adapt to rapidly evolving industrial environments (Olvera et al., 2021; Fuertes et al., 2021; Mudzar & Chew, 2022; Quintero & Namuche Maldonado, 2024).

The transformation of industrial work has likewise reshaped engineering education. Education 4.0 promotes learner-centered, competency-based, technology-enhanced, and interdisciplinary learning that prepares graduates for complex digital workplaces. Rather than emphasizing technical expertise alone, engineering education now encourages the development of higher-order thinking, innovation, communication, collaboration, creativity, and continuous professional learning. These competencies enable graduates to respond effectively to technological disruptions while supporting sustainable industrial development (Miranda et al., 2021; González-Pérez & Ramírez-Montoya, 2022; Costan et al., 2021; Cesco et al., 2021).

Globally, industries have expressed growing concern regarding the mismatch between graduates' competencies and the skills demanded by Industry 4.0 workplaces. Although universities continue producing engineering graduates, employers frequently report deficiencies in digital competencies, systems thinking, AI literacy, problem-solving, communication, and adaptability. The emergence of AI has intensified these concerns because professionals are increasingly expected to work collaboratively with intelligent technologies rather than simply perform routine technical tasks. Consequently, workforce development now emphasizes continuous reskilling and upskilling to maintain employability amid rapid technological change (Li, 2024; Saniuk et al., 2021; Akyazi et al., 2022).

In the Philippines, national initiatives promoting digital transformation and industrial modernization have encouraged higher education institutions to align engineering education with Industry 4.0 requirements. Government agencies, industries, and academic institutions continue to strengthen competency-based education, digital innovation, and industry-academe partnerships to improve graduate employability. Nevertheless, industries continue to experience competency gaps among engineering graduates, particularly in emerging technologies, automation, AI applications, and interdisciplinary problem-solving. These challenges highlight the importance of continuously evaluating workforce competency requirements from the perspective of employers who directly experience technological transformation in industrial settings.

Within the Zamboanga Peninsula, industries involved in electrical power generation and distribution, manufacturing, construction, utilities, telecommunications, and industrial services are gradually adopting automation and AI-supported technologies. As these industries embrace digital transformation, employer expectations regarding workforce competencies continue to evolve. Understanding these expectations is particularly important because industry practitioners possess firsthand knowledge of emerging occupational requirements, technological adoption, and competency deficiencies that influence organizational productivity and competitiveness. Their perspectives can provide valuable evidence for improving engineering curricula, competency standards, and workforce development strategies that respond to regional industrial needs.

Despite the growing body of literature on Industry 4.0, Education 4.0, engineering competencies, and workforce readiness, important gaps remain. First, existing studies primarily examine engineering competencies from educational or theoretical perspectives rather than from the direct experiences of employers and industry practitioners (Miranda et al., 2021; González-Pérez & Ramírez-Montoya, 2022). Second, systematic reviews indicate that there is still no consensus regarding the competencies engineers should possess in the context of Industry 4.0, demonstrating that competency frameworks continue to evolve alongside technological advances (Quintero & Namuche Maldonado, 2024). Third, previous research has generally investigated engineering competencies broadly without focusing specifically on electrical professionals' readiness for AI-enabled industrial environments, despite the increasing integration of intelligent technologies into electrical occupations (Olvera et al., 2021; Mudzar & Chew, 2022). Finally, empirical evidence from developing countries remains limited, particularly within the Philippine context and the Zamboanga Peninsula, where industrial structures, rates of technology adoption, and workforce requirements differ substantially from those reported in developed economies. This lack of localized evidence constrains higher education institutions and technical training providers from designing competency-based curricula that accurately reflect regional industry expectations and emerging artificial intelligence technologies (Quintero & Namuche Maldonado, 2024; Costan et al., 2021).

To address these research gaps, this study explores industry perspectives on the electrical competencies and artificial intelligence readiness required for workforce development in the Zamboanga Peninsula, Philippines. Specifically, the study aims to identify the knowledge, technical skills, and professional competencies expected of electrical graduates; examine how industry stakeholders perceive the influence of artificial intelligence on electrical-related occupations and the competencies necessary for future workforce competitiveness; and determine recommendations for higher education institutions and technical training providers to strengthen curriculum development and workforce preparation in response to advances in artificial intelligence. By generating localized empirical evidence from industry practitioners, the study seeks to contribute to competency-based curriculum enhancement, stronger industry-academe collaboration, and workforce development initiatives that support regional industrial competitiveness in the era of Industry 4.0 and artificial intelligence.

2. Methods

Research Design

This study employed a qualitative descriptive research design to explore industry perspectives on the electrical competencies and artificial intelligence (AI) readiness required for workforce development in the Zamboanga Peninsula, Philippines. Qualitative descriptive research is appropriate when the objective is to obtain comprehensive descriptions of participants' perspectives while remaining close to their actual experiences and language (Sandelowski, 2000; Colorafi & Evans, 2016). This design has been widely utilized in educational and organizational research to generate contextualized evidence that informs policy, curriculum development, and professional practice (Chavez & Duhaylungsod, 2023; Chavez et al., 2024).

Population and Sampling

The study involved 14 industry stakeholders from the electrical, manufacturing, energy, utilities, and industrial operations sectors in the Zamboanga Peninsula, Philippines. Participants were purposively selected because they possessed extensive professional experience in supervising, recruiting, training, evaluating, or managing electrical professionals and were knowledgeable about current industry competency requirements and the emerging role of artificial intelligence in workforce development. The participants occupied managerial, supervisory, engineering, technical, and human resource positions, enabling them to provide informed insights into the competencies expected of future electrical professionals.

Purposive sampling was employed to recruit information-rich participants capable of providing relevant and in-depth perspectives on workforce competency requirements (Patton, 2014). This sampling strategy is widely recommended in qualitative inquiry because it enables researchers to select participants with substantial experience and expertise related to the phenomenon under investigation (Lincoln & Guba, 1985). To ensure the credibility of the data, participants met the following inclusion criteria: (1) currently employed in an industry related to electrical engineering or industrial operations within the Zamboanga Peninsula, (2) possessing at least five years of relevant professional experience, and (3) directly involved in workforce supervision, recruitment, training, or competency assessment.

Research Instrument

Data were collected using a researcher-developed semi-structured interview guide consisting of open-ended questions designed to elicit participants' perspectives regarding electrical competencies and AI readiness. Semi-structured interviews provide sufficient flexibility for participants to elaborate on their experiences while ensuring consistency across interviews (Kallio et al., 2016). The interview guide was developed based on the literature on Industry 4.0 competencies, AI readiness, workforce development, and engineering education (Li, 2024; Quintero & Namuche Maldonado, 2024).

Table 1. Interview Guide Questions

Research Objective	Interview Guide Questions
1. To explore industry perspectives on the electrical competencies and artificial intelligence readiness required for workforce development in the Zamboanga Peninsula, Philippines.	1. From an industry perspective, what knowledge, technical skills, and professional competencies should electrical graduates possess to meet the current and future demands of the industrial sector? 2. How do you foresee artificial intelligence transforming electrical-related occupations, and what new competencies should future professionals develop to remain competitive in the evolving industrial environment? 3. What recommendations can you provide to higher education institutions and technical training providers to ensure that electrical graduates are equipped with competencies that align with industry needs and advances in artificial intelligence?

Data Gathering Procedure

After obtaining approval from the appropriate ethics review committee, formal permission was requested from participating organizations. Eligible participants received an invitation letter explaining the purpose of the study, voluntary participation, confidentiality measures, and data privacy protections.

Individual semi-structured interviews were conducted either face-to-face or through secure online platforms depending on participant availability. Each interview lasted approximately 45–60 minutes. With participants' informed consent, interviews were audio-recorded and supplemented by field notes documenting contextual observations.

Audio recordings were transcribed verbatim immediately after each interview. Where interviews were conducted in Filipino or in a combination of Filipino and English, transcripts were translated into English while preserving the original meanings expressed by participants.

Data Analysis

The interview transcripts were analyzed using reflexive thematic analysis following the six-phase framework developed by Braun and Clarke (2006, 2021), which provides a systematic yet flexible approach for identifying, organizing, and interpreting patterns of meaning within qualitative data. The analysis began with familiarization with the interview transcripts, followed by the generation of initial codes, searching for candidate themes, reviewing and refining themes, defining and naming themes, and producing the final thematic narrative. Coding was conducted iteratively, allowing themes to emerge through continuous engagement with the data while ensuring that they accurately represented the participants' perspectives. Throughout the analytic process, the identified themes were repeatedly compared with the original transcripts to preserve contextual meaning, maintain analytic consistency, and enhance the credibility and trustworthiness of the findings.

3. Results

Research Objective. To explore industry perspectives on the electrical competencies and artificial intelligence readiness required for workforce development in the Zamboanga Peninsula, Philippines.

Interview Question 1. From an industry perspective, what knowledge, technical skills, and professional competencies should electrical graduates possess to meet the current and future demands of the industrial sector?

Theme 1. Technical Competence

Eight participants consistently emphasized that strong technical competence remains the foundation of workforce readiness in the electrical industry. They highlighted competencies in electrical systems, industrial automation, PLC programming, motor controls, power systems, preventive maintenance, troubleshooting, electrical installation, instrumentation, renewable energy systems, quality assurance, and occupational safety. Several participants also stressed the importance of practical experience in operating industrial equipment and applying engineering principles in real-world settings.

"Our company expects electrical graduates to have a strong foundation in electrical systems, industrial automation, PLC programming, motor controls, and electrical safety." (Participant 1)

"Knowledge of PLCs, SCADA systems, sensors, industrial communication protocols, and automation programming has become increasingly important in today's industries." (Participant 9)

The findings indicate that industries continue to prioritize strong engineering fundamentals while expecting graduates to possess competencies aligned with modern industrial technologies.

Theme 2. Professional Attributes

Beyond technical expertise, six participants emphasized that successful electrical professionals should possess interpersonal and professional competencies. Communication, teamwork, leadership, adaptability, professionalism, ethical responsibility, analytical thinking, integrity, innovation, time management, and continuous learning were repeatedly identified as qualities essential for long-term career success in dynamic industrial environments.

"Technical competence is important, but employers also evaluate communication skills, professionalism, integrity, teamwork, and adaptability." (Participant 7)

"Innovation and adaptability are becoming equally valuable." (Participant 6)

These findings suggest that industries increasingly value graduates who combine technical proficiency with strong professional and interpersonal capabilities.

Interview Question 2. How do you foresee artificial intelligence transforming electrical-related occupations, and what new competencies should future professionals develop to remain competitive in the evolving industrial environment?

Theme 1. AI Transformation

Ten participants generally viewed artificial intelligence as a transformative technology that enhances industrial efficiency rather than replacing electrical professionals. AI was perceived as supporting predictive maintenance, equipment monitoring, system optimization, diagnostics, project management, production planning, quality inspection, energy management, and automation. Participants agreed that AI would augment engineering work by improving operational decision-making and reducing repetitive tasks.

"AI will transform maintenance and production by improving predictive maintenance and equipment monitoring." (Participant 1)

"Artificial intelligence will become an indispensable engineering tool that supports system design, diagnostics, maintenance planning, and operational optimization." (Participant 14)

These responses indicate that industry practitioners perceive AI as a complementary technology that enhances engineering practice while preserving the importance of human expertise.

Theme 2. Digital Readiness

Four participants emphasized that future electrical professionals should develop competencies beyond traditional engineering knowledge to remain competitive in AI-enabled industries. Frequently mentioned competencies included AI literacy, data interpretation, programming, industrial automation, machine learning, digital technologies, cybersecurity, industrial analytics, and the ability to critically evaluate AI-generated recommendations while maintaining sound engineering judgment.

"Engineers should learn how to interpret AI-generated information and use it to support technical decision-making." (Participant 2)

"Engineers who combine technical expertise with AI literacy will remain highly competitive." (Participant 14)

The findings suggest that workforce readiness increasingly depends on integrating conventional electrical engineering competencies with emerging digital and artificial intelligence capabilities.

Interview Question 3. What recommendations can you provide to higher education institutions and technical training providers to ensure that electrical graduates are equipped with competencies that align with industry needs and advances in artificial intelligence?

Theme 1. Curriculum Enhancement

Seven participants recommended updating engineering curricula to incorporate artificial intelligence, industrial automation, data analytics, simulation software, renewable energy technologies, industrial information systems, and competency-based learning. They also highlighted the importance of strengthening laboratory instruction and modernizing educational facilities to reflect current industrial technologies.

"The curriculum should integrate electrical engineering with information technology, automation, and artificial intelligence." (Participant 6)

"Universities should modernize laboratories by providing equipment similar to those used in industries." (Participant 9)

These findings emphasize the need for curriculum innovation that reflects the technological transformation occurring within modern industries.

Theme 2. Industry Collaboration

Seven participants stressed the importance of strengthening collaboration between higher education institutions and industries through internships, apprenticeships, plant immersions, collaborative research, faculty development, multidisciplinary projects, and continuous curriculum review. They believed that closer industry-academe partnerships would improve graduates' workplace readiness and ensure that educational programs remain responsive to evolving workforce demands.

"Higher education institutions should strengthen laboratory training, integrate AI applications into engineering courses, and collaborate closely with industries." (Participant 1)

"Industry and universities should regularly review engineering curricula together to ensure graduates possess competencies aligned with current workforce needs." (Participant 13)

These responses demonstrate that sustained collaboration between academia and industry is viewed as essential for preparing graduates who are capable of meeting present and future industrial competency requirements.

4. Discussion

The findings demonstrate that industries in the Zamboanga Peninsula continue to prioritize technical competence as the foundation of workforce readiness while simultaneously recognizing the increasing importance of professional competencies. Participants consistently identified electrical systems, industrial automation, PLC programming, troubleshooting, preventive maintenance, power systems, renewable energy, and workplace safety as essential competencies because these remain fundamental to industrial operations despite rapid technological transformation. This finding supports Olvera et al. (2021), who emphasized that engineers in Industry 4.0 require strong engineering fundamentals alongside emerging technological competencies. Likewise, Quintero and Namuche Maldonado (2024) concluded that multidisciplinary technical expertise remains central to engineering practice despite the growing adoption of intelligent technologies. Participants also emphasized communication, leadership, teamwork, professionalism, adaptability, and lifelong learning, reflecting the growing recognition that modern industries require engineers who can effectively collaborate within interdisciplinary and technology-driven environments. This finding reinforces Miranda et al. (2021), who argued that Education 4.0 extends engineering education beyond technical proficiency by developing higher-order thinking, collaboration, innovation, and continuous professional learning.

A notable finding was the strong emphasis on AI literacy as a complement to, rather than a replacement for, engineering expertise. Participants consistently viewed artificial intelligence as a tool that enhances predictive maintenance, diagnostics, system optimization, quality assurance, and operational decision-making while maintaining that engineering judgment remains indispensable. This emphasis on AI literacy reflects the reality that modern industrial environments increasingly rely on intelligent systems capable of generating data-driven recommendations, yet these recommendations still require human validation, contextual understanding, and technical decision-making. These findings align with Li (2024), who emphasized that Industry 4.0 requires continuous reskilling and upskilling as technological innovations redefine occupational roles. Similarly, Saniuk et al. (2021) reported that AI adoption shifts engineers' responsibilities toward analytical thinking, digital competence, and technology management rather than routine operational tasks. Unlike earlier studies that broadly discuss Industry 4.0 competencies, the present study demonstrates that employers specifically expect electrical professionals to integrate AI literacy, data interpretation, programming, automation, and cybersecurity with traditional engineering competencies. This finding extends previous literature by illustrating how AI readiness is becoming an industry expectation rather than an optional specialization, particularly for electrical professionals working in AI-enabled industrial environments.

The findings also reveal why industries in the Zamboanga Peninsula prioritize competencies related to automation, adaptability, and digital technologies. The region's electrical, manufacturing, utilities, energy, telecommunications, and industrial service sectors are gradually adopting automation, intelligent monitoring systems, and AI-supported technologies to improve operational efficiency and competitiveness. As technological transformation accelerates, industries require graduates who can readily adapt to evolving production systems without extensive retraining. Consequently, participants emphasized competencies that facilitate immediate workplace integration, including industrial automation, simulation software, digital technologies, AI applications, and interdisciplinary problem-solving. While previous studies have examined Industry 4.0 competencies from global or educational perspectives (Miranda et al., 2021; Quintero & Namuche Maldonado, 2024), the present findings contribute localized empirical evidence by demonstrating how competency expectations are shaped by the technological transition occurring within industries in the Zamboanga Peninsula. This regional perspective provides practical insights that may not be fully reflected in competency frameworks developed in highly industrialized economies, thereby enriching the broader literature on workforce development in emerging industrial regions.

Another important finding concerned participants' recommendations for curriculum enhancement and industry-academe collaboration. Participants advocated integrating AI, industrial automation, data analytics, simulation technologies, and competency-based learning into engineering curricula while expanding internships, plant immersions, faculty development, multidisciplinary projects, and collaborative curriculum review. These recommendations reflect the industry's recognition that workforce readiness cannot be achieved solely through classroom instruction but requires continuous collaboration between educational institutions and employers. This finding supports Costan et al. (2021), who emphasized that engineering education should continuously evolve alongside technological innovation to remain relevant to Industry 4.0. Similarly, González-Pérez and Ramírez-Montoya (2022) argued that sustained collaboration between higher education institutions and industry is essential for aligning curriculum content with workforce demands. The present study extends these perspectives by demonstrating that industry stakeholders do not merely expect curriculum updates but advocate for long-term partnerships that facilitate competency development through authentic industrial experiences, continuous curriculum evaluation, and faculty exposure to emerging technologies.

Overall, this study contributes to the growing body of literature on Industry 4.0 workforce development by providing evidence that future electrical professionals require a balanced integration of technical expertise, professional competencies, and AI readiness. Unlike previous studies that primarily examined engineering competencies from educational or theoretical perspectives, this research foregrounds the voices of industry practitioners who directly supervise, recruit, and evaluate electrical professionals. The findings further contribute localized evidence from the Zamboanga Peninsula, demonstrating how regional industries are responding to technological transformation through evolving competency expectations. These insights provide a valuable basis for curriculum enhancement, competency standards, workforce policy, and stronger industry-academe collaboration aimed at preparing electrical graduates for AI-enabled industrial environments while supporting regional competitiveness and sustainable workforce development.

5. Conclusion

This study explored industry perspectives on the electrical competencies and artificial intelligence (AI) readiness required for workforce development in the Zamboanga Peninsula, Philippines. The findings revealed that industries continue to prioritize strong technical competencies alongside professional attributes such as communication, adaptability, leadership, and lifelong learning. Participants also recognized AI as a transformative technology that enhances engineering practice, emphasizing the need for graduates to develop AI literacy, digital competencies, and analytical skills while maintaining sound engineering judgment.

Overall, the study highlights that preparing a future-ready electrical workforce requires continuous curriculum enhancement, stronger industry-academe collaboration, and the integration of AI-related competencies into engineering education. Aligning educational programs with evolving industry requirements will better equip future electrical professionals to thrive in Industry 4.0 and contribute to sustainable workforce development in the Zamboanga Peninsula. The study contributes localized evidence on electrical competency requirements in AI-enabled industries within a developing regional economy, providing a basis for curriculum enhancement and future workforce policy.

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