Validating Future Engineering Competencies: An Innovation System Approach in Competency Modeling through Delphi Method

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1 Introduction

This research brief presents empirical evidence from a Delphi study aimed at validating the relevance and classification of competencies essential for engineers in the Industry 5.0 era. Industry 5.0 represents a significant shift towards a more human-centric approach, integrating advanced technologies with human ingenuity to foster productivity, innovation, and efficiency [1]. Unlike Industry 4.0, which emphasized the digitization of manufacturing, Industry 5.0 focuses on sustainability, human-centricity, and resilience of industrial systems [2], [3], where engineers are key players [4]. These societal and technological shifts demand not only technical proficiency but also a blend of adaptive, interdisciplinary, and ethical capabilities [5], [6]. However, existing engineering competency models lack empirical grounding in this new context and do not sufficiently reflect the holistic skillsets now required [6]. This study addresses that gap by empirically validating a future-oriented competency framework aligned with the evolving demands of Industry 5.0.

2 Literature Review

The industrial landscape has undergone significant transformations from Industry 1.0 to Industry 4.0, and with the steep trajectory, we can reach Industry 5.0 in less than 40 years from the announcement of its predecessor in 2011 [7]. Industry 1.0 was driven by mechanization, while Industry 2.0 brought about mass production. Industry 3.0 introduced electronics and information technology, while Industry 4.0 leveraged cyber-physical systems, the Internet of Things (IoT), and big data to create smart factories [8]. With the European Commission's announcement of Industry 5.0, the focus shifted from purely technological to a value-driven advancement [2], [3] that supports human welfare, respects planetary boundaries, and fosters long-term societal prosperity [2], [9]. Some enabling technologies in Industry 5.0 are bio-inspired technologies, smart materials with embedded sensors, and digital twins [3], [5]. This calls for the future workforce to be equipped not only with technical skills but also the ability to navigate ethical, social, and environmental challenges.

Recent studies on Industry 5.0 competencies emphasize the need for a comprehensive and holistic approach to engineering education and practice. For instance, Broo et al. [10] recommend lifelong learning, transdisciplinarity, sustainability, resilience, and human-centric design. The European Commission's agenda also highlights the necessity of digital, green, cognitive, social, emotional, and practical skills [11]. Originally proposed by Daugherty and Wilson [12], Mitchell and Guile [13] contextualized the "fusion skills" in engineering education to integrate technology and human interaction. Despite these efforts, a holistic competency model specifically tailored for engineers in Industry 5.0 remains unavailable. The authors [6] hoped to fill this gap through their proposed holistic engineering competency model, following a systematic selection, appraisal, and review of literature. Guided by the Holistic Competence Model [14], 30 competencies were identified and grouped into cognitive, functional, social, and meta-competencies as shown in Figure 1.

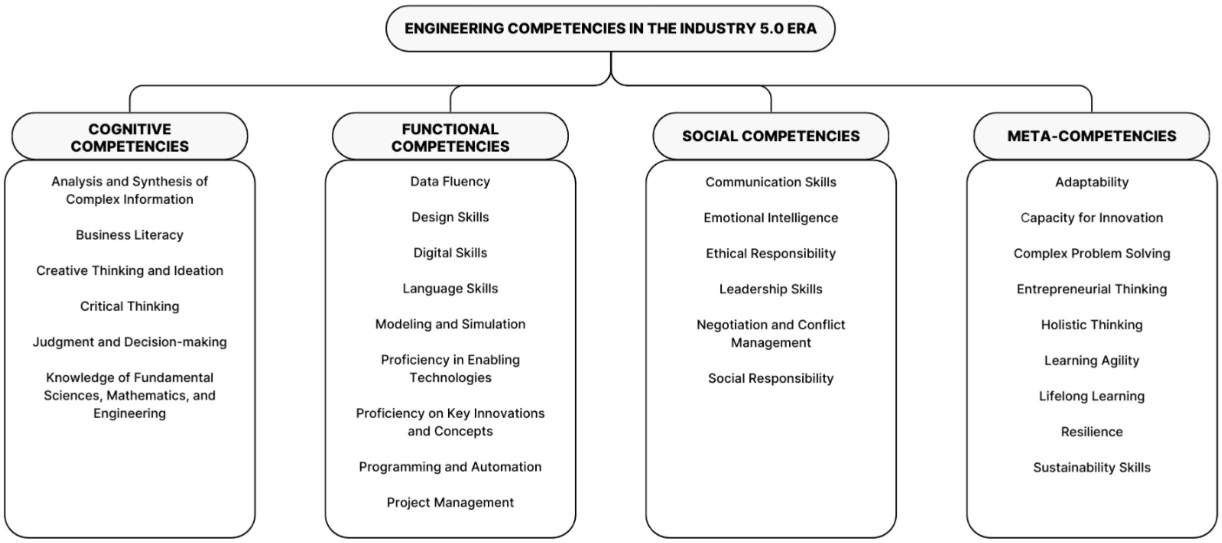

Figure 1: Engineering Competencies in the Industry 5.0 Era [6]

The review affirmed that beyond technical expertise, engineers must develop human-technology, higher-order, interdisciplinary, and adaptive competencies to effectively collaborate with human and intelligent systems. The comprehensiveness of the proposed model spans most, if not all, of the emerging Industry 5.0 competencies. However, Chan and Lee [15] believe that the holistic competency development of engineers lies in successfully identifying industry experience and expectations. Thus, empirical evidence must be established to ensure the applicability of the holistic engineering competency model [6].

The European Commission highlighted innovation as a key driver of Industry 5.0 [3]. The 2030 Agenda also expresses high expectations that innovation will play a central role in addressing SDGs [16]. To ensure that Industry 5.0 does not evolve into a big corporation's top-down policy, stakeholders from various backgrounds must be involved [17], [18]. Innovation, when viewed from a system perspective, should be the result of a sharing process among actors of an innovation ecosystem, which fits well with the logic of Industry 5.0 [16]. One robust and balanced way to harness the interactions between innovation actors is the use of Triple Helix Systems Model (THSM) developed by Ranga and Etzkowitz [19] as shown in Figure 2.

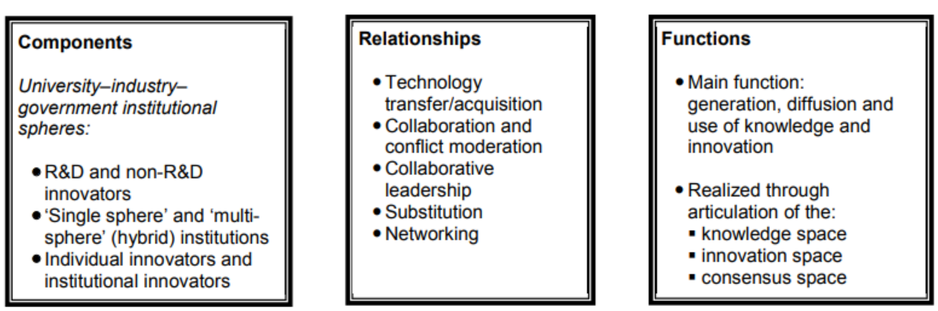

Figure 2: A synthetic representation of THSM [19]

TSHM provides a fine-grained view of innovation actors, both institutional and individual, and the relationships between them, as shown in Figure 2. The more different stakeholders involved, the greater the likelihood of innovation [20] and SDGs being attained [18]. Thus, THSM can help provide a structure for identifying the key stakeholders of Industry 5.0 who can validate the competencies needed by future engineers.

The Philippines provides an ideal context for applying the THSM to validate the proposed holistic engineering competency model due to its current economic and educational landscape. Ranked 52nd out of 67 economies in the 2024 IMD World Competitiveness Ranking, the country faces challenges in technological infrastructure, scientific infrastructure, and education, which are crucial for sustaining competitiveness [21]. Despite these challenges, the Philippines has shown remarkable progress in innovation as reported in the 2024 Global Innovation Index (GII) [22], rising from 90th to 53rd over the past decade, making it one of the highest risers alongside China, India, Iran, Morocco, and Türkiye, and has retained its "overperformer" status for the 6th consecutive year. This TH approach is essential in addressing gaps in engineering education and aligning the competencies of Filipino engineers with the needs of Industry 5.0.

To address the empirical gap in the proposed holistic engineering competency model [6], the present study aims to validate the model through expert consensus, using the Delphi method. Specifically, this study seeks to answer the following questions:

1. What are the key characteristics of experts who can validate the competencies needed in the Industry 5.0 era?
2. What competencies are relevant for engineers to thrive in the Industry 5.0 era?
3. How can these competencies be classified to improve the competency model?

Materials and Methods

The Delphi method is a structured communication technique that seeks consensus from a panel of experts through multiple rounds of surveys, with feedback provided between rounds [23]. This iterative process integrates both qualitative and quantitative data [24]. This study is Round 1 of the Delphi method applied to assess the relevance and classification of future engineering competencies for Industry 5.0. For relevance, experts were asked to assess whether each competency was relevant to Industry 5.0 by selecting Yes (Y) or No (N). Relevance helped determine if one competency must be included in the model or not, which is different from determining the level of importance of each competency. For classification, they were asked to classify each competency into cognitive, functional, social, or meta-competencies. In addition, open-ended questions were included to elicit further insights into the definitions, reclassification, potential merging of competencies, and suggestions for new competencies.

Experts were chosen based on THSM [19]. Selection criteria included:

1. Currently working or have worked in the past in any hybrid institution (e.g., technology transfer offices) in the Philippines.
2. At least 10 years of cumulative experience in the engineering profession.
3. At least 5 years of cumulative experience in teaching engineering.
4. At least 3 years of cumulative experience in any triadic relationships (e.g., networking).

Given the rigorous selection criteria, a snowball sampling technique was employed. Prospective experts filled out an online form, and only those meeting all criteria were invited to participate in the survey. Non-qualifying individuals were informed of their ineligibility. The study targeted at least 30-40 experts across the Philippines, more than the practical number for Delphi studies [25]. The survey was administered online to ensure efficient participation.

Descriptive statistics were used to analyze the quantitative data, with consensus defined as at least 75% agreement among experts on the relevance and classification of each competency. Thematic analysis was conducted on the qualitative responses to capture nuanced insights and explore convergent and divergent views. Results were presented using tables and figures to facilitate interpretation and understanding.

To ensure reliability, both the survey instrument and recruitment forms underwent validation by two experts—1 from engineering and 1 from social science. A pilot run of the instrument was conducted to identify and address any comprehension or data collection issues. The study adhered to ethical standards, with ethics clearance secured under protocol number CB-24-60.

Results and Discussion

There were 66 prospective experts sent with the recruitment form, but only 53 were eligible. Out of the 53, only 40 turned in their responses. The experts represent 9 engineering disciplines (i.e. electronics, industrial, chemical, computer, mechanical, agricultural and biosystems, electrical, environmental and sanitary, and civil engineering) and come from across the Philippines, including metropolitan hubs like Manila and regional centers across the country like Baguio City, Iloilo City, and Davao City, essential for addressing the national applicability of the competency model. As shown in Appendix A, experts exhibit the strongest engagement with universities but also very strong with industry and government. The inclusion of those affiliated with various hybrid institutions highlights the dynamic interplay of academia, industry, and government. The varying levels of involvement across five core triadic relationships reflect participants who are highly integrated into the TH ecosystem, have niche expertise, or are generalists. Their profile reveals their intricate roles and contributions, emphasizing the interplay between knowledge creation, application, and stakeholder alignment. Their diverse experiences suggest that they will lead to comprehensive and balanced recommendations.

As shown in Figure 3, cognitive competencies such as "Creative Thinking and Ideation," "Critical Thinking," and "Knowledge of Fundamental Sciences, Mathematics, and Engineering," all received a perfect 100% agreement, emphasizing their foundational relevance. The lowest within this category, "Business Literacy," still achieved a high 90%, showing its growing recognition. Functional competencies such as "Data Fluency," "Digital Skills," and "Programming and Automation" reached 100% consensus, which reflects the essential role of technical proficiency. Social competencies such as "Emotional Intelligence" and "Ethical Responsibility" achieved 100% agreement, underscoring the necessity to possess strong intrapersonal, interpersonal, and ethical skills. Meta-competencies such as "Lifelong Learning" and "Adaptability" were unanimously agreed upon, highlighting their critical role in ensuring engineers can continuously evolve with industry changes. Although "Learning Agility" and "Resilience" received lower agreements of 95%, they underscore the need for engineers to thrive in dynamic and uncertain environments. The unanimous consensus of these competencies illustrates the comprehensive nature of the proposed model and its alignment with the demands of Industry 5.0. The experts' agreement reinforces the need for a holistic approach that integrates cognitive, functional, social, and meta-competencies. The slight variation in agreement levels suggests that while all competencies are relevant, some areas, like "Business Literacy," might require further exploration of how they fit within Industry 5.0's multidimensional requirements.

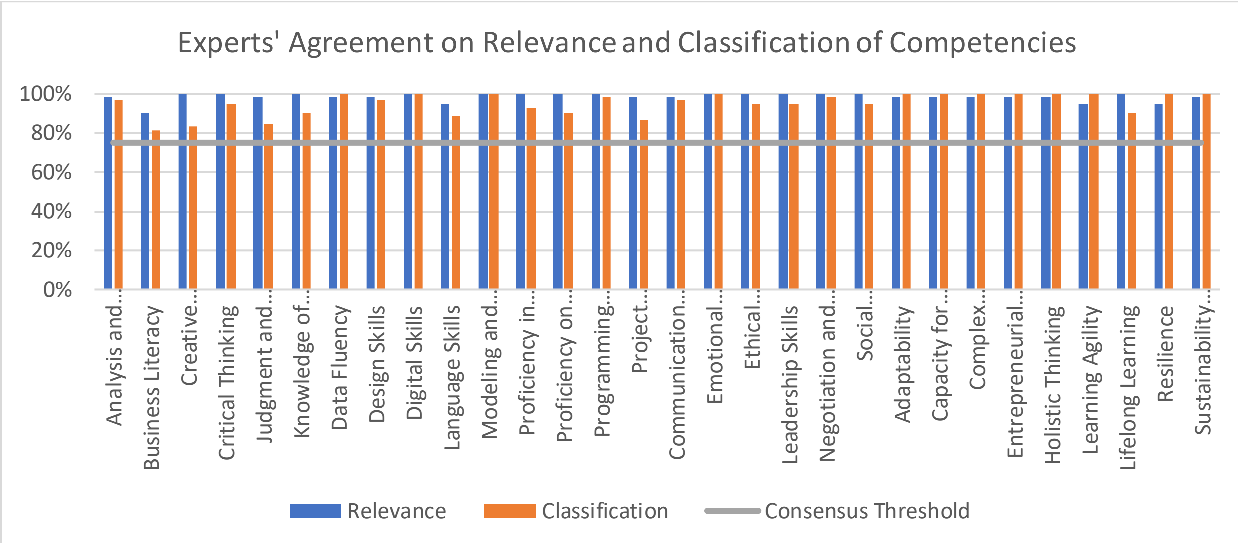

Figure 3: Experts' Agreement on Relevance and Classification of Engineering Competencies in the Industry 5.0 Era

The consensus on the classification shows that cognitive competencies received high agreement, with "Analysis and Synthesis of Complex Information" and "Critical Thinking" achieving 97% and 95%, respectively. The slightly lower agreement for "Business Literacy" (81%) and "Creative Thinking and Ideation" (83%) may suggest differing views on whether these competencies should be re-classified. Functional competencies demonstrated strong consensus, particularly for technical skills like "Data Fluency," "Digital Skills," and "Modeling and Simulation," each achieving 100% agreement. The lower agreement for "Language Skills" (89%) and "Project Management" (87%) indicates a possible discussion on their scope and definition. Social competencies were widely accepted, with most competencies like "Emotional Intelligence" and "Negotiation and Conflict Management" receiving high agreement rates, 100% and 98%, respectively, which reflects their importance in fostering effective communication and ethical decision-making. The meta-competencies showed unanimous agreement, such as in "Adaptability," "Capacity for Innovation," and "Resilience," all reaching 100%, which highlights their critical importance in a rapidly changing landscape of Industry 5.0. The high level of agreement across all competency classifications reinforces the robustness of the proposed model. The variations in agreement levels for certain competencies, particularly in the cognitive and functional domains, suggest areas where the boundaries between classifications might be blurred, warranting further clarification or adjustment. Appendix B provides details of the consensus.

Experts provided valuable insights that led to several key refinements in the competency constructs as detailed in Appendix C. For example, to enhance clarity and prevent overlap, the definition of "Creative Thinking and Ideation" was refined, distinguishing it from "Design Skills" and "Complex Problem Solving" by focusing on cognitive processes. Overlaps in descriptions were also addressed, such as those of "Lifelong Learning" and "Learning Agility." "Business Literacy" was reclassified as a Functional Competency to better reflect its practical, task-oriented nature. "Adaptability" and "Resilience" were merged to avoid redundancy to emphasize their complementary proactive and reactive roles in response to change. "Collaborative Intelligence" was added as a meta-competency to underscore both human-human and human-machine collaborations. These changes highlight a move toward a more integrated and holistic understanding of competencies essential for future engineers in dynamic and complex environments. Appendix D shows the updated competency model after Round 1.

The findings align with the central theme of merging human ingenuity with technological advancement, as highlighted by various studies. Similar to Adel [1], the findings emphasize the need for technical and soft skills, particularly in human-machine collaboration and programming. Like Güğerçin and Güğerçin [26], the findings identified cognitive efforts, complex problem-solving, leadership and social impact, technology and development skills, and management skills as critical competencies. Broo et al. [10] and Carayannis and Morawska-Jancelewicz [11] align with the inclusion of lifelong learning, multidisciplinarity, sustainability, resilience, design, data fluency, human-machine interaction, digital skills, emotional skills, and an emphasis on metacognitive skills. Although Mitchell and Guile's [13] introduces a novel dimension, a good overlap with "Collaborative Intelligence" exists as they emphasize fusion of human and machine talents within a business process to create better outcomes. Overall, the improvements in the proposed holistic engineering competency model after experts' validation promise to be comprehensive and highly applicable.

While this study involved experienced experts from diverse engineering disciplines and regions, the majority were affiliated with technology transfer offices and technology business incubators, which are primarily based in universities. This may have skewed perspectives toward academic contexts. Future studies may explore other hybrid institutions and engage their individual actors to examine potential variations in perspectives.

Conclusion and Recommendations

This study employed the Delphi method to validate a holistic engineering competency model grounded in the Triple Helix Systems Model (THSM), ensuring the integration of perspectives of hybrid innovation actors from academia, industry, and government. The engagement of experts across nine engineering disciplines and multiple regions in the Philippines enabled a well-rounded evaluation of the model's relevance and classification. Their insights refined the model's structure, highlighted the centrality of human-machine collaboration, and underscored the need to balance technical and non-technical competencies in the Industry 5.0 era. By affirming a comprehensive framework of cognitive, functional, social, and meta-competencies, this study bridges theoretical understanding with practical demands. Moving forward, the validated model offers a foundation for designing responsive curricula and training programs that prepare engineers for complex socio-technical environments. Future research should further validate the model through importance ranking and structural analysis to strengthen its utility in curriculum development, workforce planning, and policy formulation. Continued collaboration among innovation actors remains essential to align competencies with the needs of Industry 5.0.

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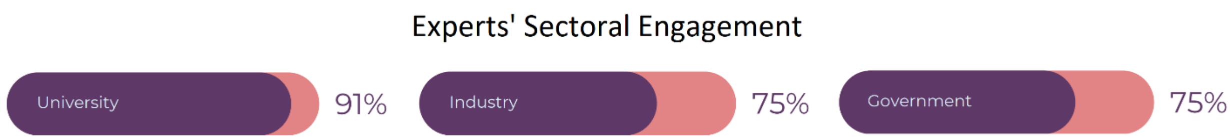
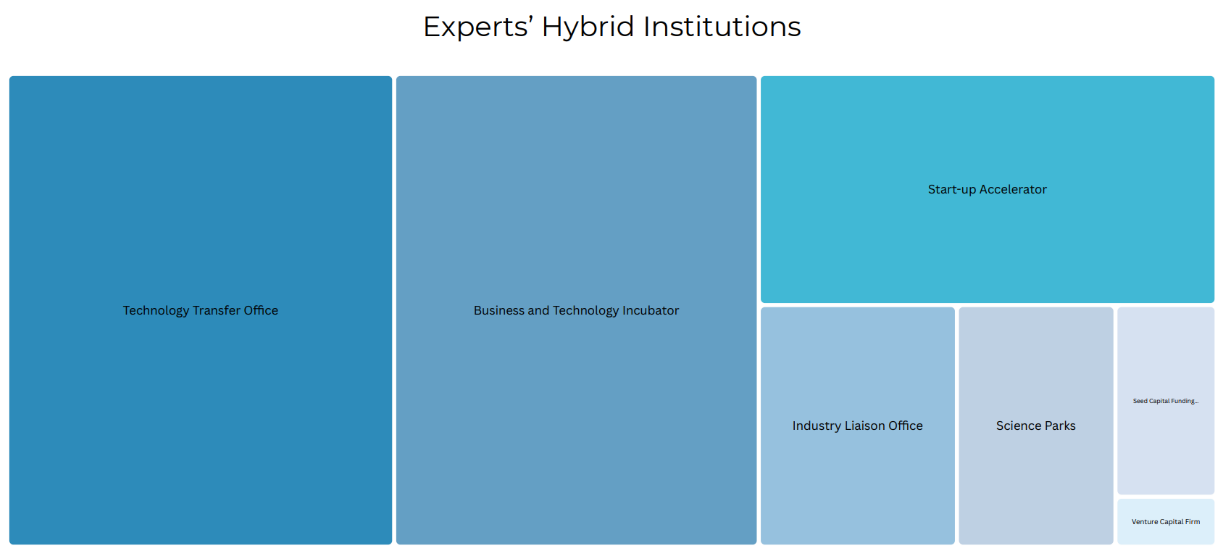
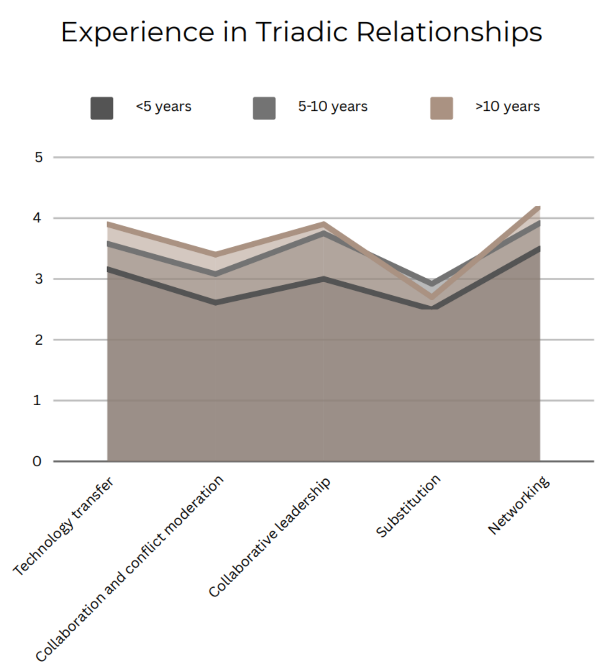
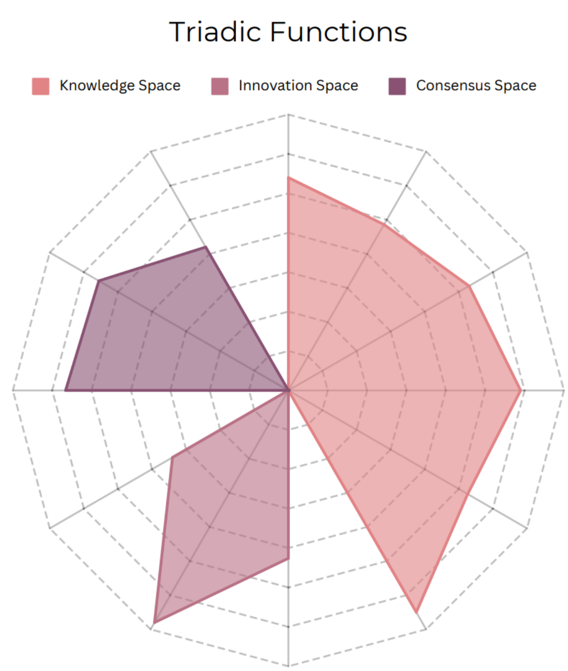
Appendices

Appendix A. Experts' Profile Based on Triple Helix Systems Model









Appendix B. Experts' Consensus on Future Engineering Competencies

Competency Construct	Relevance		Classification	
	Agreement	Consensus Met?	Agreement	Consensus Met?
Cognitive Competencies (CC)				
Analysis and Synthesis of Complex Information	98%	Yes	97%	Yes
Business Literacy	90%	Yes	81%	Yes
Creative Thinking and Ideation	100%	Yes	83%	Yes
Critical Thinking	100%	Yes	95%	Yes
Judgment and Decision-making	98%	Yes	85%	Yes
Knowledge of Fundamental Sciences, Mathematics, and Engineering	100%	Yes	90%	Yes
Functional Competencies (FC)				
Data Fluency	98%	Yes	100%	Yes
Design Skills	98%	Yes	97%	Yes
Digital Skills	100%	Yes	100%	Yes
Language Skills	95%	Yes	89%	Yes
Modeling and Simulation	100%	Yes	100%	Yes
Proficiency in Enabling Technologies	100%	Yes	93%	Yes
Proficiency on Key Innovations and Concepts	100%	Yes	90%	Yes
Programming and Automation	100%	Yes	98%	Yes
Project Management	98%	Yes	87%	Yes
Social Competencies (FC)				
Communication Skills	98%	Yes	97%	Yes
Emotional Intelligence	100%	Yes	100%	Yes
Ethical Responsibility	100%	Yes	95%	Yes
Leadership Skills	100%	Yes	95%	Yes
Negotiation and Conflict Management	100%	Yes	98%	Yes
Social Responsibility	100%	Yes	95%	Yes
Meta-competencies (MC)				
Adaptability	98%	Yes	100%	Yes
Capacity for Innovation	98%	Yes	100%	Yes
Complex Problem Solving	98%	Yes	100%	Yes
Entrepreneurial Thinking	98%	Yes	100%	Yes
Holistic Thinking	98%	Yes	100%	Yes
Learning Agility	95%	Yes	100%	Yes
Lifelong Learning	100%	Yes	90%	Yes
Resilience	95%	Yes	100%	Yes
Sustainability Skills	98%	Yes	100%	Yes

Criteria for Consensus: at least 75% Agreement for each competency construct.

Appendix C. Experts' Key Comments and Changes Made in the Competency Model

Cognitive Competency (CC) Constructs (Original)	Summary of Key Comments/Suggestions	Changes Made
Analysis and Synthesis of Complex Information: Ability to examine complex system, their parts, and their interactions and combine information to produce new information.	Emphasize systems-thinking, systems integration, and the need for a systemic perspective under CC1. (Experts 5, 36)	Construct name and definition were refined to highlight the focus on systems and systems thinking without losing the aspect of analysis and synthesis of complex information.
Business Literacy: Knowledge and understanding of the financial, accounting, and marketing functions of an organization.	Include of economics principles, business integration, and the transfer of Business Literacy to Functional Competencies. (Experts 6, 19, 29, 36)	Definition was refined to include the external economic factors affecting organizations. Reclassified as under Functional Competency to better align with its nature as a specialized, task-oriented competency of an engineer.
Creative Thinking and Ideation: Ability to develop, implement, and communicate a considerable number of original ideas or expand on existing ideas.	Focus on potential overlaps with design skills, complex problem-solving, and innovation capacity. (Experts 1, 2, 5, 29, 38, 40)	Definition was refined for clarity and emphasis on the cognitive processes of creativity and to delineate from the scope and avoid overlap with said other competencies.
Critical Thinking: Ability to systematically analyze, interpret, and evaluate information, arguments, or situations.	None	None
Judgment and Decision-making: Ability to assess situations, weigh consequences, and form conclusions to help choose the best course of action among alternatives.	None	None
Knowledge of Fundamental Sciences, Mathematics, and Engineering: Understanding of fundamental scientific principles, mathematical methods, and core engineering concepts.	Highlight the need for deeper theoretical understanding of human-machine interactions, AI, robotics, IoT, and foundational computer science concepts, alongside the application of statistical and numerical analysis. (Experts 3, 5, 14)	Definition was refined to emphasize the importance of understanding and application of technological foundations and statistical techniques to the solution to real-world problems.
Functional Competency (CC) Constructs (Original)	**Summary of Key Comments/Suggestions**	**Changes Made**
Data Fluency: Ability to deal with challenges in accessibility, availability, quality, volume, and variety of industrial data.	Integrate data ethics, connecting data problems to industry challenges, and ensuring data safeguarding. (Experts 14, 28)	Definition was refined to emphasize the complexities and challenges in data and in handling them and to put emphasis on it practical and transformative outcomes.
Design Skills: Ability to conceptualize, develop, and implement solutions that address complex problems while considering user needs and requirements, multiple constraints, and tradeoffs.	Integrate design skills with creative thinking in problem solving and consider other user requirements and needs in engineering design. (Experts 19, 29, 40)	Definition was refined to emphasize that Complex Problem Solving often precedes Design Skills, and that the latter operationalizes the solutions identified from the former through design process.
Digital Skills: Ability to function effectively and safely within a digital environment through activities such as searching, creating, managing, and communicating digital content and solving problems through digital technologies and techniques.	None	None
Language Skills: Proficiency to use the appropriate language to effectively comprehend, express and collaborate in a given work setting.	Highlight the importance of conveying technical concepts, understanding technical documents, and incorporating multilingual and contextual communication skills in a global context. (Experts 13, 14, 19, 35)	Definition was refined to clearly differentiate from Communication Skills by emphasizing multilingual capabilities and technical literacy.
Modeling and Simulation: Ability to create and manipulate representations of real-world products and processes and subject them to different scenarios to achieve expected outcomes.	None	None
Proficiency in Enabling Technologies: Adeptness in utilizing cutting-edge technologies to optimize operational efficiency and achieve organizational goals.	Replace of 'cutting-edge' with 'relevant' to better align with the common engineering practice of applying established technologies rather than just those that are emerging. (Expert 3)	Definition was refined to reflect a balance between innovation and practical industry application.
Proficiency on Key Innovations and Concepts: Understanding and application of innovative principles and methodologies to drive organizational growth and success.	None	None
Programming and Automation: Ability to develop, implement, and optimize software solutions and automated processes to streamline operations and enhance productivity.	None	None
Project Management: Ability to plan, organize, and manage tasks, resources, and time to achieve project goals efficiently and effectively.	None	None
Social Competency (SC) Constructs (Original)	**Summary of Key Comments/Suggestions**	**Changes Made**
Communication Skills: Ability to convey information effectively, listen actively, and engage empathetically with others to build meaningful relationships and facilitate collaboration and understanding within diverse contexts.	Highlight the need to encompass both oral and written communication, context clues, global communication, and the dual role of communication skills in task-specific and interpersonal contexts. (Experts 2, 5, 14, 19, 35)	Definition was refined for clarity and emphasis of different forms of communications
Emotional Intelligence: Ability to recognize, understand, and manage one's own emotions, as well as accurately perceive and effectively respond to the emotions of others.	None	None
Ethical Responsibility: Ability to recognize and adhere to moral principles and values when making decisions to contribute to the well-being of individuals and society.	Stress the importance of addressing biases, assessing ethical implications, ensuring societal alignment, and integrating ethical decision-making into engineering practices. (Experts 4, 5, 14, 33, 35)	Definition was refined to emphasize professional standards and ethical use and development of technologies.
Leadership Skills: Capacity to articulate vision, inspire others to share vision, and leverage influence for collective efforts toward achieving personal goals and organization goals.	None	None
Negotiation and Conflict Management: Ability to resolve disputes, facilitate compromise, and reconcile differences to reach a mutually beneficial agreement.	None	None
Social Responsibility: Capacity to understand the impact of individual and collective decisions and actions on the well-being and sustainability of the society.	Emphasize active participation in community development, collaboration with local communities to address SDGs, and ensuring safety and health in engineering work. (Experts 4, 33)	Definition was refined to highlight both the awareness of broader community roles and the practical aspect of engaging with and contributing to those communities.
Meta-competency (MC) Constructs (Original)	**Summary of Key Comments/Suggestions**	**Changes Made**
Adaptability: Ability to navigate and thrive in changing environments by continuously adjusting one's mindset, behaviors, and strategies to meet new challenges and opportunities.	Highlight the capacity to respond to dynamic environments, adjust strategies, recover from challenges, and ensure smooth collaboration. (Experts 4, 13, 23, 35)	Merged with Resilience and refined definition to avoid overlap and emphasize their interconnectedness as proactive and reactive aspects of dealing with changes.

Capacity for Innovation: Ability to generate novel ideas, approaches, and solutions, driving forward creative and transformative change across various domains and contexts.	Shift from Business Literacy to Innovation Literacy and highlight the role of innovation in problem-solving.	Definition was refined to emphasize the broader scope of implementing creative ideas to drive innovation, which goes beyond and avoid overlap with Creative Thinking and Ideation.
Complex Problem Solving: Ability to identify ill-defined problems, formulate multiple viable solutions, and choose the best solution for optimal outcomes in diverse contexts.	None	None
Entrepreneurial Thinking: Ability to identify opportunities, create value, and take calculated risks to drive positive change for self and the community.	None	None
Holistic Thinking: Ability to comprehend complex systems, their parts, and their interrelationships, considering multidisciplinary insights and taking into consideration broader organizational and societal goals.	Consider integrating the need for global collaboration and the intersection between Adaptability and Holistic Thinking. (Experts 5, 19)	Definition was refined to emphasize understanding the system as a whole, including external factors and implications, fostering a more integrative and comprehensive viewpoint.
Learning Agility: Capacity to rapidly acquire and apply new knowledge, skills, and perspectives across contexts, enabling effective adaptation to the ever-changing personal and professional demands.	Highlight the ability to quickly learn and adapt to new tools, technologies, and environments, as well as the merging of Learning Agility with Lifelong Learning. (Experts 4, 18, 35)	Definition was refined to emphasize the focus on the speed and flexibility of learning in various situations.
Lifelong Learning: Capacity to continuously seek, acquire, and apply new knowledge, skills, and experiences throughout life and career for personal and professional development and adaptation.	Highlight the merging of Learning Agility with Lifelong Learning, the incorporation of a growth mindset, and the encouragement of continuous upskilling. (Experts 1, 18, 24)	Definition was refined to emphasize a long-term, ongoing process of education and self-improvement.
Sustainability Skills: Ability to integrate environmental, social, and economic considerations into decision-making processes and actions for long-term viability and positive impact.	Emphasize the alignment with Sustainable Development Goals, the evaluation of impacts in engineering decisions, and the need to differentiate from Social Responsibility while potentially addressing specific environmental constructs. (Experts 3, 4, 33)	Construct name and definition were refined to concentrate on integrating sustainability directly into professional practices and solutions, highlighting the environmental, social and economic dimensions of sustainability. This also avoids overlaps with Ethical Responsibility and Social Responsibility.

Additional Meta-competency (MC) Constructs	Summary of Key Comments/Suggestions	Reason
Collaborative Intelligence: Ability to effectively collaborate within multidisciplinary teams, across global and cultural boundaries, and with intelligent systems to co-create innovative solutions, leveraging diverse strengths and fostering a cohesive team environment.	Highlight the necessity of multidisciplinary collaboration and leveraging human-machine strengths to address complex challenges. (Experts 1, 3, 4, 5, 13, 16, 35, 38)	Added to emphasize that collaboration in Industry 5.0 goes beyond traditional teamwork as it includes not only working across disciplines and cultures, but even with intelligent systems, emphasizing global collaboration and the increasing human-machine partnerships.

Appendix D. Revised Holistic Engineering Competency Model after Round 1 Delphi Study