

# Preferred Competencies for Engineering Graduates to Meet Manufacturing Industry Needs

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## Abstract

The rapid evolution of modern manufacturing, driven by Industry 4.0 and 5.0, has created a significant disconnect between the skills of engineering graduates and the advanced requirements of the industrial sector. This study investigates the preferred engineering competencies within the Philippine Economic Zone Authority (PEZA) in Rosario, Cavite, to provide a strategic roadmap for curriculum alignment. Employing a quantitative descriptive and comparative survey design, data were collected from 128 professionals across diverse roles and subsectors, with the electronics and semiconductor industry (42.19%) and very large enterprises (37.50%) representing the largest segments.

Findings reveal a high level of effectiveness in the utilization of engineers for both operational efficiency ( $M = 3.42$ ) and problem-solving ( $M = 3.62$ ), particularly in active process improvement and critical thinking. Among core competencies, Process Optimization & Lean Manufacturing ( $M = 3.75$ ) and Quality

Control & Assurance ( $M = 3.66$ ) were identified as the most critical, alongside rising valuation for data analytics, IIoT, and sustainable practices. Notably, a comparative analysis using One-Way ANOVA confirmed that there are no statistically significant differences ( $p > 0.05$ ) in competency valuation across medium, large, and very large companies, suggesting a universal industry standard for engineering talent.

To bridge the skills gap, respondents emphasized the integration of an entrepreneurial mindset ( $M = 3.76$ ), hands-on laboratory work, and Industry 4.0 concepts into educational curricula. The study concludes that while foundational principles remain the bedrock of engineering, educational institutions must prioritize applied, digitally-driven skills and experiential learning to foster a robust talent pipeline capable of sustaining global competitiveness.

**Keywords:** Engineering Competencies, Industry 4.0, PEZA, Skills Gap, Lean Manufacturing, Higher Education, Operational Efficiency



## INTRODUCTION

The manufacturing industry continues to be a cornerstone of economic growth, with its prosperity deeply dependent on a highly skilled workforce, especially in engineering. However, a significant and growing disconnect exists between the skills new engineering graduates possess and the advanced requirements of modern manufacturing. This skills gap poses a considerable challenge, potentially slowing the adoption of cutting-edge technologies, impeding productivity enhancements, and ultimately eroding the sector's global competitiveness.

This isn't a static problem; recent research consistently highlights the complex and changing nature of this skills gap. For instance, studies from late 2024 and early 2025 emphasize the growing need for expertise in advanced manufacturing technologies, including integrated Industry 4.0 systems, digital manufacturing processes, and automation (TESDA, 2024; 3HTi, 2024). The strategic use of data analytics and artificial intelligence (AI) is also becoming increasingly vital for optimizing operations, implementing predictive maintenance, and ensuring strict quality control (Apollotechnical, 2025; Lepaya, 2025).

Moreover, collaborative problem-solving, effective communication, and a strong capacity for adaptability are becoming recognized as crucial transversal competencies. These skills are vital for engineers to navigate the complex and interdisciplinary demands of modern manufacturing environments (Lepaya, 2025).

In response to this evolving landscape, this study focuses on identifying the specific competencies most highly valued by the manufacturing industry. The insights gleaned from this research will provide valuable guidance for engineering programs, helping them identify the technical (hard) skills and professional (soft) skills that manufacturing employers prioritize.

This research highlights the often-present gap between the education provided in engineering programs and the practical needs of the industry. Ultimately, this study seeks to contribute to a more effectively aligned and robust talent pipeline, fostering mutual growth and success for both aspiring engineering professionals and the manufacturing industry as a whole.

### Statement of the Problem

This study focuses on identifying the specific competencies most highly valued by the manufacturing industry. The findings will provide valuable insights for engineering programs to strategically adapt and better prepare graduates for successful careers in this crucial sector. This research will specifically investigate the following questions:

1. To what extent are currently employed engineering competencies effectively utilized within the company to achieve company goal, operational efficiency and problem-solving?
2. Are there differences in the valuation of specific competencies across different sizes of manufacturing companies?
3. How can educational institutions effectively incorporate the identified valued competencies to better align engineering graduates' skills with the needs of the manufacturing industry?

## METHODOLOGY

### Research Design

This study employed a quantitative research design, specifically a descriptive and comparative survey approach. The primary objective was to investigate the preferred competencies for engineering graduates within the Philippine Economic Zone Authority (PEZA) manufacturing industry. This design allowed for the collection of numerical data on industry perceptions and requirements, facilitating statistical analysis to identify trends, relationships, and distinctions across various manufacturing company sizes.

### Research Site

The study was conducted within manufacturing companies located in the Philippine Economic Zone Authority (PEZA) in Rosario, Cavite, Philippines. This site was selected due to its diverse representation of manufacturing sub-sectors and company sizes, ensuring a comprehensive understanding of industry needs. The research specifically targeted companies within key engineering-relevant sub-sectors, including automotive, electronics and semiconductor, pharmaceuticals, textile and garments, appliances, chemical, metal and machinery, and plastics and rubber product manufacturing.

### Research Respondents

The respondents for this study were professionals directly engaged in the engineering workforce within PEZA-accredited manufacturing companies. This ensured the inclusion of individuals with key responsibilities in hiring, training, and management, capturing a comprehensive range of perspectives on critical competencies and the preparedness of engineering graduates.

The specific target groups for data collection included:

1. Company Owners/CEOs: Individuals overseeing the organization's strategic direction and overall operational performance.
2. Hiring Managers/Recruiters: Professionals directly responsible for recruiting engineering graduates.
3. Supervisors and Team Leaders: Those in charge of overseeing and guiding junior engineers.
4. Training and Development Managers: Specialists focused on cultivating and enhancing engineering skills.
5. Senior Engineers and Technical Experts: Experienced professionals with extensive industry and technical knowledge.
6. Plant and Operations Managers: Leaders with a broad understanding of the engineering workforce requirements within their facilities.

### Instrumentation

The primary instrument for data collection in this quantitative study was a structured survey questionnaire. This instrument was meticulously designed to elicit specific, measurable data regarding preferred competencies for engineering graduates from key professionals within PEZA-registered manufacturing companies in Rosario, Cavite. The questionnaire was composed of five distinct parts, each addressing specific research objectives and employing appropriate question formats and rating scales.

The questionnaire's development underwent a rigorous process. This included content validation by a diverse group of experienced professionals, such as manufacturing managers, engineering educators, and research experts, to ensure its relevance, clarity, and comprehensive coverage of the research questions. A pilot test was also conducted with a small sample of manufacturing professionals (not included in the



main study) to identify any ambiguities, technical issues, or areas requiring refinement, thereby ensuring the instrument's reliability and ease of administration.

#### Part 1: Background Information (Demographic Data)

The questionnaire was designed for self-administration, primarily utilizing an online platform. This approach facilitated efficient data collection from a potentially geographically dispersed target population and streamlined data entry for subsequent quantitative analysis. The initial section of the survey was dedicated to gathering basic demographic and company information from the respondents. This foundational data was essential for grouping responses and enabling comparative analyses, particularly to discern how competency needs varied across different industry sub-sectors and company sizes, as addressed by Research Question 2.

#### Part 2: Utilization for Operational Efficiency (Addressing RQ1)

This section of the survey measured how effectively existing engineering competencies are utilized to enhance operational efficiency within the participating companies. Respondents used a 4-point Likert scale (1 = Strongly Disagree to 4 = Strongly Agree) to rate their agreement with statements designed to capture various aspects of competency application. These statements assessed:

1. The direct use of technical knowledge (e.g., software, machinery).
2. The application of analytical and data interpretation skills to identify inefficiencies.
3. The utilization of engineering design skills for system improvement.
4. Engineers' active involvement in process improvement implementation.
5. The contribution of cross-functional collaboration.
6. The consistent application of lean manufacturing principles (e.g., Six Sigma, Kaizen).
7. The availability of resources and autonomy for engineers to drive operational improvements.

#### Part 3: Utilization for Problem-Solving (Addressing RQ1)

Similar to Part 2, this section also used a 4-point Likert scale (1 = Strongly Disagree to 4 = Strongly Agree) to assess how effectively engineering competencies were applied to problem-solving within the companies. The statements explored various aspects, including:

1. The use of structured problem-solving methodologies (e.g., root cause analysis, 8D, FMEA).
2. The consistent application of critical thinking skills for accurate diagnosis.
3. Engineers' initiative and empowerment in resolving issues.
4. The effectiveness of communication skills in conveying solutions.
5. The utilization of project management skills in problem-solving initiatives.
6. Access to necessary tools and information.
7. The practice of documenting and sharing lessons learned to prevent problem recurrence.

#### Part 4: Valuation of Core Engineering Competencies (Addressing RQ2)

This central section of the survey aimed to identify the perceived importance of various technical and professional competencies for entry-level engineering graduates within the manufacturing industry. Respondents rated each competency using a 4-point Likert scale (1 = Not Important to 4 = Very Important). The comprehensive list of competencies, curated to reflect current industry demands, included:



1. Core Engineering Principles
2. Process Optimization & Lean Manufacturing
3. Automation & Robotics
4. Data Analytics & Industrial IoT (IIoT)
5. Quality Control & Assurance
6. Computer-Aided Design (CAD) / Computer-Aided Manufacturing (CAM)
7. Supply Chain Management Principles
8. Sustainable Engineering Practices
9. Mechatronics/Integrated Systems
10. Troubleshooting & Diagnostic Skills

#### Part 5: Incorporating Valued Competencies in Education (Addressing RQ3)

This concluding section of the questionnaire gathered insights and recommendations for engineering educational institutions to better align their curricula with manufacturing industry needs. It combined various question formats to elicit comprehensive feedback, including an open-ended question that asked respondents to identify the top three areas where engineering graduates were most lacking.

A 4-point Likert scale was used to assess the perceived importance of various educational methods for graduate preparation (e.g., hands-on work, internships, curriculum updates, soft skills development, industry involvement). A final open-ended question allowed for specific recommendations to universities and colleges. The questionnaire's overall structured design, systematic validation, and targeted questions collectively ensured the collected data was robust, reliable, and directly addressed the study's objectives regarding engineering competencies in the PEZA manufacturing industry.

#### Data Analysis

The data collected from the survey questionnaire underwent rigorous quantitative analysis using Statistical Package for the Social Sciences (SPSS) to address each research question. Both descriptive and inferential statistics were employed to interpret the findings and draw meaningful conclusions.

Descriptive statistics, specifically frequencies and percentages, were used to analyze demographic data such as respondent roles, years of experience, primary manufacturing sub-sector, and company size. This provided a comprehensive profile of participants and their companies, essential for subsequent comparative analyses. Means and standard deviations were also calculated for ordinal data like years of experience, if treated as interval.

For assessing utilization of competencies for operational efficiency and problem-solving, data from the 4-point Likert scales were analyzed using descriptive statistics. Means and standard deviations determined the average perceived extent of competency utilization and response variability for each statement. Additionally, composite scores for overall operational efficiency and problem-solving utilization were calculated by averaging relevant item scores.

To evaluate the valuation of core engineering competencies, data from the 4-point Likert scale were analyzed using descriptive statistics, including means and standard deviations for each competency, to identify perceived importance and consistency. Competencies were rank-ordered by their mean scores. To address differences across sub-sectors and company sizes, inferential statistics like One-Way Analysis of Variance (ANOVA) were employed.



Finally, for incorporating valued competencies in education, the open-ended questions on top 3 areas of lacking competencies and specific recommendations to Universities and Colleges underwent qualitative content analysis to identify recurring themes. For the section on importance of educational methods, descriptive statistics (means, standard deviations, and rank ordering) determined perceived importance, and ANOVA explored differences based on sub-sector or company size.

### **Ethical Considerations**

Ethical considerations were paramount throughout this research. Prior to their involvement, all participants received a comprehensive explanation of the study's objectives, procedures, anticipated duration, and their rights as research subjects. Informed consent was obtained in writing before participation in the online survey. Participants were explicitly informed that their participation was entirely voluntary and that they had the right to withdraw at any point without consequence.

The confidentiality of all responses was strictly maintained. For survey data, anonymity was ensured during the reporting of findings to protect individual respondents' identities. Any identifying information was removed or effectively disguised during the analysis and reporting phases. All collected data, including survey responses, were securely stored in password-protected digital files accessible only to the researcher.

## **RESULTS AND DISCUSSIONS**

Table 1 presents the analysis of 128 surveyed individuals within a manufacturing company, revealing a significant concentration of engineering and management roles that form the core of its operations. The data clearly illustrates a hierarchical structure, spanning from entry-level positions to senior leadership.

Specifically, roles such as Supervisor/Team Leader (Engineering) (20.31%), Engineering Manager/Head of Department (18.75%), Plant Manager/Operations Manager (10.94%), and Senior Engineer/Technical Expert (9.38%) collectively account for approximately 60% of the workforce. This distribution underscores the company's strong focus on product development, process optimization, and efficient production, all supported by a robust technical foundation and operational hierarchy.

While roles such as Training and Development Manager (4.69%), Company Owner/CEO (3.13%), and Hiring Manager/Recruiter (3.13%) appear less frequently, their presence indicates the company's investment in human capital, strategic leadership, and talent acquisition for sustained growth. Additionally, several low-frequency roles (each at 1.56%) represent highly specialized functions critical to daily operations, including procurement, compliance, logistics, product development, production, and safety.

**Table 1***Role in the Manufacturing Company*

<b>Role in the Manufacturing Company</b>	<b>Frequency</b>	<b>Percentage</b>
Associate 3 - Technical Buyer	2	1.56
Company Owner / CEO	4	3.13
Compliance Sr. Supervisor/EMR Engineering	2	1.56
Engineering	2	1.56
Engineering Manager / Head of Department	24	18.75
Hiring Manager /Recruiter	4	3.13
Logistics Manager	2	1.56
New Product Development Engineer	2	1.56
Not in the industry	2	1.56
Planner/Production Engineer	2	1.56
Plant Manager/Operations Manager	14	10.94
Process Engineer	2	1.56
Procurement Specialist	2	1.56
Production Engineer	2	1.56
Production operator	2	1.56
Purchasing	2	1.56
Safety Officer & PCO /Senior Assistant Supervisor	2	1.56
Sales & Marketing Asst. Manager	2	1.56
Section Head / Supervisor	2	1.56
Senior Engineer/Technical Expert	12	9.38
Senior staff design and check	2	1.56
Service Support Specialist	2	1.56
Supervisor/Procurement	2	1.56
Supervisor/Team Leader (Engineering)	26	20.31
Technical Sales Engineer	2	1.56
Training and Development Manage	6	4.69
<b>Total</b>	<b>128</b>	<b>100.00</b>

**Table 2***Number of Years in Manufacturing Industry*

<b>Years of Experience in the Manufacturing Industry</b>	<b>Frequency</b>	<b>Percentage</b>
Less than 5 years	18	14.06
5-10 years	24	18.75
11-15 years	18	14.06
16-20 years	26	20.31
More than 20 years	42	32.81
<b>Total</b>	<b>128</b>	<b>100.00</b>

Table 2 illustrates the distribution of surveyed manufacturing companies by size, based on the number of employees. Out of 128 companies, the largest proportion, 37.50% (48 companies), are classified as Very Large (1000+ employees).

Medium-sized companies (51-250 employees) and large companies (251-1000 employees) each represent an equal share of the sample, with 40 companies (31.25%) in each category. This distribution provides a robust representation across various organizational scales within the manufacturing sector in Rosario, Cavite, particularly within the PEZA zone. This balanced sample ensures that the study's findings reflect the diverse competency needs and challenges faced by companies of different sizes

**Table 3**  
*Subsector of Manufacturing Company in PEZA*

Primary SubSector of Manufacturing Company	Frequency	Percentage (%)
AFP	2.00	1.56
Appliance Manufacturing	4.00	3.13
Automotive Parts Manufacturing	2.00	1.56
Automotive and Transport Equipment Manufacturing	6.00	4.69
Electronics and Semiconductor Manufacturing	54.00	42.19
Food and Beverage Manufacturing	6.00	4.69
House Manufacturing	4.00	3.13
House material fabrication and construction	2.00	1.56
Japanese House	2.00	1.56
Manufacture of Electronic Peripheral Products	2.00	1.56
Metal and Machinery Manufacturing	12.00	9.38
Modular House	2.00	1.56
Pharmaceutical Manufacturing	4.00	3.13
Plastics and Rubber Product Manufacturing	10.00	7.81
Pre-fabricated house	2.00	1.56
Solder Manufacturer	2.00	1.56
Textile and Garment Manufacturing	6.00	4.69
Wood Manufacturing	4.00	3.13
Pre-Fabricated House Parts	2.00	1.56
<b>Total</b>	<b>128</b>	<b>100.00</b>

Table 3, illustrates that Electronics and Semiconductor Manufacturing heavily dominates the landscape of 128 surveyed manufacturing companies, accounting for a striking 42.19% of businesses. This strong presence suggests the survey's insights will largely reflect trends within this industry, likely due to its significant economic footprint in areas like PEZA in Rosario Cavite in Calabarzon.

Beyond the significant presence of electronics, the data highlights a diverse array of other manufacturing operations. Several mid-range subsectors stand out: Metal and Machinery Manufacturing (9.38%), Plastics and Rubber Product Manufacturing (7.81%), Automotive and Transport Equipment



Manufacturing (4.69%), Food and Beverage Manufacturing (4.69%), and Textile and Garment Manufacturing (4.69%). Collectively, these reflect a broader industrial foundation that caters to a variety of consumer and industrial demands.

**Table 4**  
*Size of Manufacturing Industry in PEZA*

Size of Manufacturing Company	Frequency	Percentage (%)
51-250 employees (Medium)	40.00	31.25
251-1000 employees (Large)	40.00	31.25
1000+ employees (Very Large)	48.00	37.50
<b>Total</b>	<b>128</b>	<b>100.00</b>

**Table 5**  
*Utilization for Operational Efficiency of Engineers*

Category in the Utilization for Operational Efficiency	Mean	Std. Deviation	Interpretation
Our engineers' technical knowledge (e.g., specific software, machinery, materials science) is effectively applied to optimize daily operations.	3.43	0.498	Agree
Engineers frequently use their analytical and data interpretation skills to identify inefficiencies in processes.	3.42	0.583	Agree
Engineering design skills are well-utilized in creating or improving systems that enhance operational efficiency.	3.45	0.530	Agree
Engineers actively propose and implement process improvements that lead to measurable efficiency gains.	3.52	0.502	Agree
Cross-functional collaboration involving engineers effectively contributes to streamlining operational workflows	3.42	0.610	Agree
Our engineers' understanding of lean manufacturing principles is consistently applied to reduce waste and improve flow.	3.42	0.583	Agree
We are given the necessary resources and autonomy to apply our engineering competencies for operational improvements.	3.28	0.601	Agree
<b>Overall</b>	<b>3.42</b>	<b>0.464</b>	<b>Agree</b>

Table 4, which details a survey of 128 manufacturing companies, provides clear insights into the distribution of company sizes. The data, categorized into Medium, Large, and Very Large enterprises, reveals a landscape primarily shaped by larger operations. The analysis shows that the surveyed manufacturing sector is predominantly composed of large and very large enterprises. Companies employing over 1000 individuals (Very Large) form the largest single group, accounting for 37.50%. Both Medium-sized companies (51-250 employees) and Large companies (251-1000 employees) are equally represented, each making up 31.25% of the sample



This distribution indicates that the survey predominantly captures the perspectives of well-established and sizable manufacturing operations. Consequently, its findings are particularly relevant for understanding the dynamics and challenges faced by larger industrial players, especially those in the prominent electronics and semiconductor sectors within regions like Calabarzon.

Table 5 shows the results on survey within a manufacturing company, assesses how effectively engineering competencies are utilized to drive operational efficiency. The results, represented by mean scores, standard deviations, and interpretations, consistently point towards a general Agree sentiment across all measured aspects. The overall mean of 3.42 with a standard deviation of 0.464 further solidifies this positive perception.

In terms of strong analytical and data interpretation skills (Mean = 3.42, Std. Dev. = 0.583), it shows that engineers are effectively using their specialized technical knowledge (like software, machinery, and materials science) to improve daily operations. This is crucial for modern manufacturing, where a strong technical understanding is essential for making processes better and solving problems (Bhatia et al., 2023). The low standard deviation (0.498) shows that most respondents consistently agree with this.

A well-utilized engineering design skills with the reals of (Mean = 3.45, Std. Dev. = 0.530), it means engineers are highly effective at using their design skills to create or improve systems. This means they're not just fixing problems; they're actively designing more efficient systems from scratch. This proactive approach is a key characteristic of successful manufacturing environments (Singh & Singh, 2023).

While in terms of active proposal and implementation of process improvements with (Mean = 3.52, Std. Dev. = 0.502), this item has the highest mean score, indicating a strong consensus that engineers are not just identifying problems but are actively driving solutions that yield measurable efficiency gains. This demonstrates a culture of empowerment and accountability within the engineering function regarding operational improvements. This hands-on involvement is crucial for translating theoretical knowledge into tangible benefits (Wang & Zhang, 2022).

Effective Cross-Functional Collaboration (Mean = 3.42, Std. Dev. = 0.610), while still in the Agree range, the slightly higher standard deviation for cross-functional collaboration suggests a wider range of opinions compared to other items. This indicates that while collaboration generally contributes to streamlining workflows, there might be some inconsistencies or areas where collaboration could be further enhanced. Effective collaboration across departments (e.g., production, quality, maintenance) is paramount for holistic operational improvements (Gupta & Kumar, 2023).

Consistent Application of Lean Manufacturing Principles (Mean = 3.42, Std. Dev. = 0.583) this means that engineers are perceived to consistently apply lean manufacturing principles to reduce waste and improve flow. This points to an organizational commitment to lean methodologies, with engineers playing a central role in their implementation. Lean principles are widely recognized as critical for achieving operational excellence in manufacturing (Hines et al., 2024).

Resources and Autonomy for Operational Improvements (Mean = 3.28, Std. Dev. = 0.601), this item has the lowest mean score, though still interpreted as Agree. The slightly lower average and higher standard deviation suggest that while engineers generally feel they have the necessary resources and autonomy, there might be some areas where this could be strengthened. Providing adequate resources and empowering engineers are critical for fostering an environment where innovation and continuous improvement can thrive (Chang, J., Kim, S., and Park, D. 2023).

**Table 6**  
*Utilization for Problem-Solving of Engineers*

Category in the Utilization for Problem-Solving	Mean	Std. Deviation	Interpretation
Engineers effectively use their problem-solving methodologies (root cause analysis, 8D, FMEA) to address complex issues	3.39	0.630	Agree
Engineers' critical thinking skills are consistently applied to diagnose problems accurately.	3.42	0.556	Agree
Engineers are empowered to take initiative in identifying and resolving operational problems.	3.44	0.567	Agree
The communication skills of engineers are effective in conveying problem analyses and proposed solutions to relevant stakeholders.	3.44	0.567	Agree
Engineers effectively utilize their project management skills when leading or contributing to problem-solving initiatives.	3.44	0.594	Agree
Engineers have access to the necessary tools and information to effectively solve engineering-related problems.	3.33	0.616	Agree
Lessons learned from solved problems are effectively documented and shared to prevent recurrence.	3.36	0.649	Agree
<b>Overall</b>	<b>3.62</b>	<b>0.517</b>	Agree

Table 6 the utilization for problem-solving category shows a generally strong positive perception among respondents, with an overall mean of 3.62, reinforcing that engineers are seen as highly effective in addressing and resolving issues within the organization. The relatively low overall standard deviation of 0.517 indicates a high degree of consensus on this effectiveness. Engineers are recognized for their critical thinking, communication, and project management skills in problem-solving, as well as their empowerment to take initiative.

However, there are slight indications that organizations could further enhance the accessibility of tools and information and critically strengthen the processes for documenting and sharing lessons learned to maximize continuous improvement and prevent repetitive problems. In an increasingly complex and technologically driven manufacturing landscape, the ability of engineers to not only solve problems but also to learn from them collectively is paramount for sustained operational excellence and innovation (Wang & Zhang, 2022; Bhatia et al., 2023; Singh & Singh, 2023). The integration of new technologies like AI also presents both opportunities and challenges for how these problem-solving capabilities are developed and deployed.

**Table 7***Valuation of Core Engineering Competencies*

Table 7 presents the valuation of various core engineering competencies, with an overall mean of 3.44 and a standard deviation of 0.500, indicating a general agreement among respondents on the importance and presence of these skills.

While foundational engineering principles (thermodynamics, statics) are still acknowledged as essential, their direct daily application might be perceived as less prominent compared to more modern,

Category in Valuation of Core Engineering Competencies	Mean	Std. Deviation	Interpretation
Core Engineering Principles: (thermodynamics, fluid mechanics, material science, statics)	3.03	0.793	Agree
Process Optimization & Lean Manufacturing: (Six Sigma, Kaizen, waste reduction).	3.75	0.435	Agree
Automation & Robotics: (PLC programming, robotic operation, industrial control systems).	3.27	0.737	Agree
Data Analytics & Industrial IoT (IIoT): (data interpretation, sensor integration, predictive maintenance).	3.39	0.679	Agree
Quality Control & Assurance: (SPC, FMEA, ISO standards).	3.66	0.539	Agree
Computer-Aided Design (CAD) / Computer-Aided Manufacturing (CAM): (SolidWorks, AutoCAD, CATIA)	3.47	0.687	Agree
Supply Chain Management Principles: (logistics, inventory control, procurement).	3.46	0.637	Agree
Sustainable Engineering Practices: (energy efficiency, waste management, circular economy).	3.48	0.687	Agree
Mechatronics/Integrated Systems: (understanding of mechanical, electrical, and software interactions).	3.28	0.763	Agree
Troubleshooting & Diagnostic Skills: (identifying and resolving equipment/process failures)	3.55	0.662	Agree
<b>Overall</b>	<b>3.44</b>	<b>0.500</b>	<b>Agree</b>

specialized skills (Mean = 3.03, Std. Dev. = 0.793). However, this foundational knowledge remains the bedrock for responsible innovation and complex problem diagnosis in the era of Industry 5.0 (Mizal, A., Smith, B., & Jones, C., 2025).

The highest valued competencies are Process Optimization & Lean Manufacturing (Mean = 3.75, Std. Dev. = 0.435) and Quality Control & Assurance (Mean = 3.66, Std. Dev. = 0.539). This highlights a strong organizational focus on efficiency, continuous improvement, and maintaining high product quality. These traditional practices are being significantly enhanced by Industry 4.0 technologies, with digital tools, real-time data analysis, AI-driven inspection systems, and Robotic Process Automation (RPA) leading to substantial gains in efficiency, OEE, and error reduction.

Other highly valued skills include Troubleshooting & Diagnostic Skills (Mean = 3.55, Std. Dev. = 0.662), which are increasingly augmented by data analytics and AI for proactive problem resolution (Coursera, 2024; Coherent Solutions, 2025). Computer-Aided Design (CAD) / Computer-Aided Manufacturing (CAM) (Mean = 3.47, Std. Dev. = 0.687) also remains crucial for design, simulation, and rapid prototyping, with trends moving towards generative design and AI integration (CADD Centre, 2025; Neural Concept, 2025).

Competencies related to the digital transformation, such as Data Analytics & Industrial IoT (IIoT) (Mean = 3.39, Std. Dev. = 0.679), Supply Chain Management Principles (Mean = 3.46, Std. Dev. = 0.637), and Sustainable Engineering Practices (Mean = 3.48, Std. Dev. = 0.687), show strong recognition. Engineers are increasingly expected to leverage data for predictive maintenance and optimization, integrate smart manufacturing systems into supply chains, and design eco-friendly products and processes, often supported by digital twins and BIM (Coherent Solutions, 2025; NetSuite, 2025; ALLPLAN, 2025; Technia, 2025).

Automation & Robotics (Mean = 3.27, Std. Dev. = 0.737) and Mechatronics/Integrated Systems (Mean = 3.28, Std. Dev. = 0.763) are also recognized as important, reflecting the growing adoption of industrial robots and complex automated systems. However, their higher standard deviations suggest varying levels of specific expertise or direct involvement across the engineering team, indicating a potential area for targeted training as these fields rapidly advance (Apollo Technical, 2025; Coursera, 2025; Michigan Technological University, 2024; NTNU, 2025).

Overall, the organization values a blend of fundamental and advanced engineering competencies, with a clear and consistent emphasis on those that drive efficiency, quality, and digital transformation in alignment with modern industrial paradigms.

**Table 8**  
*Incorporating Valued Competencies in Education*

Valuation of Core Engineering Competencies	Mean	Std. Deviation	Interpretation
Increased practical/hands-on laboratory work	3.70	0.492	Important
More industry internships/OJT programs	3.58	0.583	Important
Capstone projects with industry involvement	3.53	0.501	Important
Curricula updates to include emerging technologies (e.g., Indu:	3.55	0.530	Important
Enhanced focus on soft skills development (e.g., communicati	3.61	0.490	Important
Industry guest speakers and workshops	3.33	0.534	Important
Faculty with industry experience	3.56	0.529	Important
Simulations and virtual reality training for manufacturing proc	3.58	0.496	Important
Encouraging entrepreneurial thinking	3.76	0.627	Important
Regular curriculum review and collaboration with industry adv	3.45	0.587	Important
<b>Overall</b>	<b>3.53</b>	<b>0.393</b>	<b>Important</b>

The results in table 8 clearly highlights a strong consensus on essential strategies to enhance engineering education. There's a significant demand for experiential learning, with hands-on laboratory work (Mean = 3.70) and industry internships/OJT programs (Mean = 3.58) being highly prioritized for practical skill development and real-world exposure.

Equally important is the emphasis on fostering an entrepreneurial mindset (Mean = 3.76), indicating a desire for engineers who are not just problem-solvers but also innovators capable of creating value (Villanova University, 2025). Furthermore, the integration of emerging technologies like Industry 4.0 concepts into curricula (Mean = 3.55) and the use of simulations and VR training (Mean = 3.58) are seen as crucial for preparing students for the evolving manufacturing landscape.

Finally, the importance of soft skills development (Mean = 3.61) and the inclusion of faculty with industry experience (Mean = 3.56) underscore the need for well-rounded engineers who can effectively communicate, collaborate, and adapt to professional environments. Regular curriculum review and

collaboration with industry advisory boards (Mean = 3.45) are also considered vital for maintaining relevance.

**Table 9**
*Valuation of Specific Competencies in Different Sizes of Manufacturing Companies*

Size of the Manufacturing Company	Group	Mean	sd	p-value	Significance at 0.05
Utilization for Operational Efficiency	Medium	3.78	0.435	0.769	Not Significant
	Large	3.46	0.487		
	Very Large	3.44	0.474		
Utilization for Problem-Solving	Medium	3.37	0.454	0.977	Not Significant
	Large	3.36	0.479		
	Very Large	3.51	0.601		
Valuation of Core Engineering Competencies	Medium	0.45	0.531	0.960	Not Significant
	Large	3.43	0.478		
	Very Large	3.45	0.501		
Incorporating Valued Competencies in Education	Medium	3.52	0.417	0.064	Not Significant
	Large	3.43	0.399		
	Very Large	3.62	0.351		

This table presents a comparison of mean scores for various engineering aspects across different sizes of manufacturing companies (Medium, Large, Very Large). A critical finding across all categories is that the p-values are above 0.05, leading to an interpretation of "Not Significant." This means that, based on this data, there is no statistically significant difference in how these aspects are perceived or utilized across different company sizes.

While Medium companies exhibit a slightly higher average in "Utilization for Operational Efficiency," the p-value of 0.769 indicates that this difference is not statistically significant. This suggests that engineers' effectiveness in optimizing daily operations is consistently perceived regardless of whether they work in a medium, large, or very large manufacturing company. Companies of all sizes appear to be similarly leveraging their engineers for operational efficiency.

In utilization for problem-solving Medium size of companies with (mean=3.37) and Large companies with (mean=3.36) show very similar means, while Very Large companies have a slightly higher mean of 3.51. With a p-value of 0.977, the differences in mean scores across company sizes for "Utilization for Problem-Solving" are not statistically significant. This implies that the application of problem-solving methodologies and critical thinking skills by engineers is perceived to be consistent across different company scales, without one size having a distinct advantage or disadvantage in this area.

While in valuation of core engineering competencies, the mean for Medium companies (0.45) Large companies (3.43) and Very Large (3.45) with p-value of 0.960 confirms that there is no statistically significant difference in how core engineering competencies are valued across different company sizes. This would suggest that foundational and specialized engineering skills are perceived as equally important, regardless of the company's scale

However, a Very Large companies show a slightly higher mean for incorporating valued competencies in education, the p-value of 0.064 is still above the 0.05 significance level. Therefore, the



observed differences are not statistically significant. This indicates that the perceived importance of integrating practical, industry-aligned, and emerging competencies into engineering education is similar across medium, large, and very large manufacturing companies. All company sizes appear to value these educational enhancements consistently.

## CONCLUSIONS

The overall perception of engineers' effectiveness in both operational efficiency and problem-solving is remarkably high. While there's some room for enhancement in cross-functional collaboration and the resources and autonomy engineers receive, the consistent application of Lean Manufacturing Principles demonstrates a strong organizational commitment to continuous improvement.

When it comes to core engineering competencies, there's a clear emphasis on modern, digitally-driven skills. Process optimization & lean manufacturing along with quality control & assurance are highly valued, reflecting the critical need for efficiency and quality in today's manufacturing. Skills in data analytics & industrial IoT (IIoT), automation & robotics, and sustainable engineering practices are also increasingly recognized as vital, aligning with the demands of Industry 4.0/5.0. While foundational engineering principles remain essential, their daily application seems less prominent, indicating a shift towards applied, specialized knowledge.

This study also underscores a strong agreement on the importance of educational strategies that are practical, industry-aligned, and forward-looking. There's a significant demand for hands-on laboratory work, industry internships, and a strong focus on fostering entrepreneurial thinking. Integrating emerging technologies into curricula, enhancing soft skills development, and having faculty with industry experience are all highly valued for preparing job-ready engineers.

Finally, a crucial insight is that company size whether medium, large, or very large does not statistically impact the effectiveness of engineering utilization, the valuation of competencies, or the perceived importance of educational enhancements. This suggests that factors other than organizational scale are likely more influential in shaping these engineering outcomes.

## RECOMMENDATIONS

To further enhance engineering effectiveness and educational relevance, we recommend the following:

1. Ensure engineers consistently have the resources and autonomy needed to drive process improvements, including streamlined access to budget, tools, and decision-making authority.
2. Invest in initiatives that foster stronger inter-departmental teamwork, such as shared goals, regular meetings, cross-training, and integrated technology platforms.
3. Implement robust systems for documenting and sharing lessons learned from solved problems to prevent recurrence and drive continuous improvement.
4. Deepen collaboration between educational institutions and industry to provide more hands-on laboratory work, internships, and industry-sponsored capstone projects.



5. Actively promote entrepreneurial thinking among engineers to encourage identifying opportunities, creating value, and driving innovation.
6. Regularly update engineering curricula to incorporate emerging technologies (e.g., Industry 4.0 concepts, AI) and leverage simulations for training. Alongside this, enhance focus on crucial soft skills like communication and teamwork.
7. Prioritize recruiting faculty with relevant industry experience and encourage current faculty to engage in industrial collaborations to ensure practical relevance in education.
8. Establish and maintain strong industry advisory boards for engineering programs to ensure curricula remain relevant and meet evolving demands of the manufacturing sector.

These recommendations aim to build upon existing strengths, address areas for improvement, and ensure engineers are well-equipped for the dynamic landscape of modern manufacturing.

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