INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue XXVI January 2026| Special Issue on Education

Methodological Competency Gaps among Robotic Engineering Technology Graduates in Malaysia's Automotive Manufacturing Industry

Nur Ain Binti Md Lukmanul Hakim[1]*, Mohamad Rasidi Pairan[2], Mohamad Ikram Zakaria[3]

Faculty of Educational Sciences and Technology, Universiti Teknologi, Malaysia

***Corresponding Author**

DOI: https://doi.org/10.47772/IJRISS.2026.1026EDU0055

Received: 19 January 2026; Accepted: 25 January 2026; Published: 04 February 2026

ABSTRACT

The Malaysian Critical Occupations List 2019/2020 published by Talent Corporation Malaysia identifies industrial and production engineers including robotics engineers and technologists as hard to fill occupations within the manufacturing sector. Although the report attributes this challenge to limited experience and inadequate technical skills the deeper causes of these workforce gaps remain insufficiently examined within the industry context. This study aims to empirically validate and contextualize the findings by investigating methodological competency issues among robotics engineering technology graduates employed in Malaysia's automotive manufacturing industry. A qualitative research design was adopted utilizing semi structured interviews with five industry experts representing three major automotive manufacturing companies. Data were analysed using thematic analysis to identify patterns and insights related to graduates workplace performance and skill readiness. The analysis revealed nine recurring methodological competency issues which include weak problem solving ability, lack of critical thinking, unsystematic task execution, limited project management competency, difficulty in applying theoretical concepts, low technical proficiency, overdependence on supervision, weak mental resilience, and insufficient real world industrial exposure. Overall the findings indicate that the hard to fill status of robotic engineering technologist positions is driven largely by methodological competency gaps particularly in systematic problem solving, critical judgment, and structured task execution alongside foundational technical and workplace adaptation challenges.

Keywords: Methodological Competency; Robotic Engineering Technologist; Automotive Manufacturing; Industry 4.0; Malaysia

INTRODUCTION

The rapid advancement of automation, robotics, and digital technologies under the Industry 4.0 paradigm has significantly transformed manufacturing systems worldwide. Modern manufacturing environments are no longer characterised solely by manual operations or isolated automated processes (Petropoulos et al., 2026; Sherif & Salonitis, 2025). Instead, they increasingly comprise highly integrated cyber physical systems that require engineers to operate at the intersection of physical production processes, digital technologies, and data driven decision making. In such contexts, technical knowledge alone is insufficient. Engineers are increasingly expected to demonstrate methodological competencies, including critical thinking, complex problem solving, project coordination, and the ability to translate theoretical knowledge into practical and context sensitive solutions (Beagon & Bowe, 2023; Karwowski et al., 2025; Rawboon et al., 2021).

In response to these global developments, many countries have prioritised workforce readiness as a strategic agenda to sustain advanced manufacturing competitiveness. In Malaysia, the importance of developing industry ready engineering talent has been formally acknowledged through national workforce planning instruments such as the Critical Occupations List (COL) 2019/2020 (Talent Corporation Malaysia, 2020). The COL identifies industrial and production engineer as one of the hard to fill occupations within the manufacturing sector, citing persistent challenges related to lack of relevant work experience, inadequate technical skills, and a limited pool of suitable applicants. These concerns are further reinforced by industry input from the Machinery & Engineering Industries Federation (MEIF), which highlights robotic engineers and robotic engineering technologists as particularly difficult to recruit due to niche skill requirements, prolonged skill acquisition periods, and limited hands on exposure among graduates.

In the context of highly automated automotive manufacturing, roles such as robotic engineering technologists often involve activities in automation integration, production optimisation, and system level troubleshooting. While Karwowski et al. (2025) emphasize these functions as part of the broader grand challenges in industrial and systems engineering particularly under themes of digital transformation, human machine collaboration, and complex systems integration. Su et al. (2025) highlight how digital tools in engineering education can prepare future professionals for such environments by enhancing skills in simulation, virtual experimentation, and digital problem solving. This alignment between industrial practice and educational innovation reflects trends in the international literature on robotics, automation, and advanced manufacturing roles.

Studies on resilient production systems emphasize the importance of root cause analysis in supporting maintenance and reliability (Ito, 2023). Similarly, research on robotics in lean manufacturing highlights how automation contributes to efficiency and reduced downtime (Nikolić et al., 2023). These themes align with broader literature on fault detection and diagnosis in industrial robotics, where engineers leverage sensor data and data driven techniques to monitor system health and troubleshoot complex faults. Research on Industry 4.0 emphasizes the role of continuous data monitoring and advanced analytics in supporting root cause problem solving and quality improvement in manufacturing (Vo et al., 2020). In parallel, studies on digital tools in engineering education highlight how AI and simulation technologies can prepare future engineers to interpret process data and adapt operating parameters in real time (Su et al., 2025). Together, these perspectives point to the growing importance of data driven approaches for optimizing production workflows and supporting zero defect strategies in advanced manufacturing contexts.

From an organisational perspective, recent studies on agile transformation in the automotive industry demonstrate that project management approaches increasingly require technical staff to participate in planning, task coordination, and risk management across the project lifecycle (Cao & Choudhary, 2023). In parallel, research on robotics for lean manufacturing improvement shows that engineering decisions regarding robot system selection often rely on multi criteria decision making models, balancing constraints such as cost, capacity, flexibility, safety, and system reliability (Nikolić et al., 2023). Taken together, these studies illustrate a set of technical and organisational functions operating and maintaining automated systems, diagnosing complex faults, optimising production workflows, supporting project management activities, and making timely engineering decisions under operational constraints that, although typically attributed to roles labelled as robotics engineer or automation engineer, are functionally equivalent to the expectations outlined in the official job scope of robotic engineering technologists (Ministry of Human Resources Malaysia, 2020).

As one of Malaysia's key manufacturing sectors, automotive production increasingly relies on robotics, automation systems, and advanced control technologies across core processes such as welding, assembly, inspection, and planning. Evidence of this trend can be seen in Malaysian automotive assembly lines, where automated conveyors, robotic arms, and AI technologies are integrated to improve balancing and throughput (Rasib et al., 2025). Similarly, AI-driven smart inspection systems have been adopted in an automotive plant in Selangor to enhance quality control and operational efficiency (Jessica Anne et al., 2025)

At the sectoral level, studies on smart manufacturing readiness and Industry 4.0 adoption highlight that robotics, smart inspection, and digital control technologies are becoming central to competitiveness among Malaysian automotive manufacturers (Gen et al., 2025; Radzi & Ghani, 2021). While these technical demands are well documented in the broader literature on Industry 4.0 and advanced manufacturing, Malaysian studies continue to report persistent challenges in graduate employability and skill mismatch. For instance, research has unpacked structural issues in graduate employability policies (Moo & Da Wan, 2023), examined the overeducation dilemma (Wei & Yew, 2024), and analysed the economic risks faced by graduates in a *"gaji cukup makan"* economy (Saari et al., 2025). Together, these studies suggest that despite the strategic importance of sectors like automotive manufacturing, employers face ongoing difficulties in recruiting graduates adequately prepared to meet multifaceted technological demands.

Existing literature on engineering employability and Industry 4.0 skills has largely focused on technical competency gaps, such as insufficient programming and digital skills, limited knowledge of automation and system integration, and weak familiarity with advanced manufacturing tools like simulation, cyber physical systems and additive manufacturing (Islam, 2022; Khan & Mourad, 2025; Rikala et al., 2024). While these studies provide valuable insights, other research highlights the often overlooked methodological dimension of competence that is, how graduates think, analyse problems, justify decisions, and execute tasks systematically in real industrial environments (Caton et al., 2022; Rawboon et al., 2021). Emerging work on digital fluency further suggests that weaknesses in analytical reasoning, systems thinking, and structured decision making may significantly hinder graduates' performance in smart manufacturing settings (Cain & Coldwell-Neilson, 2024). However, empirical evidence linking these methodological issues to national workforce concerns remains limited, particularly within the automotive manufacturing context.

Moreover, many previous studies adopt survey based or multi sector approaches that do not sufficiently capture the complexity of workplace practices in high-risk, automation-intensive industries. For example, systematic reviews of engineering employability instruments show that most rely on generic survey tools, offering breadth but little depth into industry specific realities (Zhan et al., 2025). Similarly, studies on Industry 4.0 employability often use multi-sector frameworks that highlight broad skill gaps but fail to explain how these play out in particular workplaces such as automation heavy industries (Ba Qatyan & Bin, 2022; Ismaili et al., 2025). Reviews of automation and employment impacts also remain dominated by survey evidence, leaving open questions about how automation reshapes day-to-day practices in engineering roles (Barbieri et al., 2019). In contrast, the few industry-grounded case studies such as Nioata et al. (2025) on smart manufacturing safety in automotive plants demonstrate the complexity of workplace practices that survey methods often overlook. As a result, there is a lack of qualitative evidence explaining why roles such as robotic engineering technologists remain hard to fill despite an increasing number of engineering graduates entering the labour market.

Against this backdrop, the present study seeks to empirically validate and contextualise the issues identified in the Malaysian Critical Occupations List by examining methodological competency challenges among robotic engineering technology graduates in the automotive manufacturing industry. Responding to calls for more context specific investigations into engineering competencies (Rawboon et al., 2021), this study adopts an in depth qualitative approach using semi structured interviews with experienced industry professionals in production engineering, automation, and technical quality roles in automotive manufacturing sector in Malaysia. By focusing on a single, strategically important manufacturing sector, the study provides nuanced insights into the root causes of graduate under preparedness and contributes to a deeper understanding of how methodological competency gaps shape workforce shortages in advanced manufacturing.

The findings of this study contribute to both theory and practice. Theoretically, the study reframes the discussion on engineering skill gaps by shifting the focus from purely technical deficiencies to methodological competencies such as analytical reasoning and structured decision-making. Practically, the results provide evidence that can inform national workforce policies and guide higher education institutions, industry stakeholders, and policymakers in aligning engineering education with the evolving demands of Malaysia's automotive manufacturing sector.

METHODOLOGY

This study adopted a qualitative research design using semi structured interviews to explore methodological competency issues among robotic engineering technology graduates in Malaysia's automotive manufacturing industry. The qualitative approach was selected to capture rich, contextualised insights into workplace practices, decision making processes, and real world challenges that cannot be adequately measured through surveys alone. In this study, the term "robotic engineering technology graduates" refers specifically to graduates employed in robotic engineering technologist roles within automotive manufacturing environments. Where the term "graduates" is used, it refers to this same group unless stated otherwise.

Five industry experts were purposively selected for this study based on their relevance to the research objectives and their direct involvement in automotive manufacturing operations. This sample size was deemed appropriate as the study prioritised depth of expert insight rather than statistical generalisation, consistent with qualitative exploratory research. The inclusion criteria required participants to have a minimum of five years of professional experience, as well as substantial experience supervising or working closely with engineering graduates in robotics and automation related roles. All participants were employed within automotive manufacturing environments that utilise advanced automation and robotic systems. The selected experts were drawn from three automotive manufacturing companies in Malaysia and represented a range of functional roles, including production engineering, automation, maintenance, and technical quality as shown in Table 1. This diversity of professional backgrounds enabled the study to capture comprehensive and credible insights into methodological competency issues across different operational contexts within the automotive manufacturing sector.

Table 1 Participant for this research

Participant (P)	Company	Years of experience	Position
1	A	11	Head of Technical Quality
2		19	Senior Engineer of Trim and Final
3	B	14	Maintenance and Facilities Engineer
4	C	5	Automation Technician and Drafter
5		5	Executive in Production Engineering

A pilot interview was conducted with one domain expert to refine the interview protocol. Interviews were conducted virtually, audio recorded with participants' consent, and transcribed verbatim. Ethical approval was obtained prior to data collection, and all participants provided informed consent. The data were analysed using thematic analysis supported by ATLAS.ti software, following Braun and Clarke (2006) six phase framework. Start with familiarisation with data, initial coding, theme development, theme review, defining themes, and reporting. This approach enabled systematic identification of recurring patterns related to methodological competencies and graduate readiness for automotive manufacturing roles.

FINDINGS AND DISCUSSION

The thematic analysis revealed nine interrelated methodological competency issues experienced by robotic engineering technology graduates in Malaysia's automotive manufacturing industry. These issues encompass graduates' weak complex problem solving capability, lack of critical thinking and sound engineering judgment, unsystematic execution of tasks, and limited project management skills. In addition, graduates were found to struggle with applying theoretical knowledge to real industrial contexts, demonstrating low technical proficiency and limited ability to adapt to workplace tools and systems. The findings also highlight graduates' tendency to depend heavily on senior engineers, accompanied by weak mental resilience and fear of making independent decisions. Furthermore, insufficient real world industrial exposure during training was identified as a contributing factor that exacerbates these competency gaps. Although each of these issues represents a distinct aspect of methodological weakness, they are closely interconnected and collectively shape graduates' overall readiness for highly automated automotive manufacturing environments. Consequently, these issues are discussed in an integrated manner to reflect the complexity and interdependence of real world engineering practice rather than as isolated deficiencies.

One of the most prominent issues identified in this study concerns graduates' limited capability in complex problem solving and systematic troubleshooting within automotive manufacturing environments. Industry experts reported that fresh graduates often require an extended period merely to identify the root cause of technical problems, with some failing to progress beyond the diagnostic stage; as one expert noted, *"fresh graduates usually take a longer time to understand the root cause of a problem and figure out the solution"* (P1), while another highlighted that *"in some cases, it took two days at worst, even up to two weeks just to detect the problem"* (P4). These findings indicate that graduates struggle to apply structured analytical reasoning and systems thinking, which are critical competencies in highly automated production systems, and they align with previous research suggesting that critical thinking and problem solving capacity among engineering learners remains uneven or underdeveloped in relation to contemporary industrial challenges, including Industry 4.0 contexts (Muhamad et al., 2019). In the Malaysian context, Saleh and Lamsali (2019) found that employers were less satisfied with graduates' applied problem solving capabilities despite their basic engineering knowledge. Osman et al. (2025) comfirm that problem solving and troubleshooting skills are among the least satisfactory attributes of graduate engineers as perceived by manufacturing managers. Global evidence further underscores this issue, with the World Economic Forum (2023) identifying complex problem solving as one of the most critical skill gaps in automation intensive industries.

Closely related to this issue is the lack of critical thinking and engineering judgment in decision-making processes. Experts described situations in which graduates follow standard operating procedures without questioning underlying causes or validating decisions using engineering logic. For instance, one participant explained that many graduates *"just follow procedures without thinking critically about why the sensor malfunctioned"* (P1), while another remarked that *"sometimes, decisions are made without any engineering basis"* (P3). Such practices suggest a reliance on procedural compliance rather than analytical reasoning, reflecting an educational emphasis on rote learning rather than independent judgment. This finding is supported by recent studies showing weak critical thinking dispositions among Malaysian undergraduates (Lijie et al., 2025), limited adoption of problem based learning approaches that foster independent judgment (Hadibarata et al., 2023), and employers' concerns about engineering graduates' poor decision making skills in industrial contexts (Phang et al., 2025)

Another recurring theme relates to unsystematic task execution and weak project management capability. Participants observed that graduates often lack planning discipline, fail to consider operational constraints such as lead time and downtime, and struggle to coordinate tasks effectively. One expert noted that graduates are *"not very systematic in their work… a lot of it is done without proper planning"* (P2), while another emphasised that *"they don't factor in lead time or downtime… those things are developed through experience"* (P5). In addition, difficulties in managing timelines and delegating tasks were highlighted, with P2 stating that graduates are *"weak when it comes to managing projects… scheduling timelines or delegating tasks."* These findings are consistent with recent studies showing persistent weaknesses in project management discipline among Malaysian engineering graduates (Phang et al., 2025), evidence that traditional teaching approaches limit systematic task execution (Hadibarata et al., 2023), and global recognition that project management remains one of the most underdeveloped graduate skills in automation-intensive industries (World Economic Forum, 2023).

Graduates' difficulty in applying theoretical knowledge to real world practice was strongly evident. Although exposed to engineering tools such as FMEA, control diagrams, and simulation software during their studies, many were reported to struggle with practical implementation. As one participant explained, *"not everyone who learns FMEA actually uses it in the industry. Most just study it to pass"* (P5), while another observed that *"they struggle to implement what they've learned"* (P4). This persistent gap between theoretical instruction and workplace application is consistent with Moo and Da Wan (2023), who found that graduates often fail to transfer classroom knowledge into authentic industrial contexts, and Wei and Yew (2024) , who reported limited confidence among graduates in applying engineering tools within production environments. Further evidence is provided by Jery et al. (2024) who highlighted that industrial training experiences are frequently short in duration and misaligned with workplace realities, leaving graduates underprepared for systematic implementation.

In addition, experts highlighted significant deficiencies in both basic technical proficiency and adaptability as several participants described situations where graduates were unable to interpret engineering symbols or utilize fundamental measurement tools. For example, one expert remarked that *"there are times when they can't even interpret symbols like actuators"* (P3), while another shared, *"I handed a vernier caliper to one, and they didn't know how to use it"* (P4). Furthermore, a notable resistance to adapting to industry specific software was observed as one participant explained that graduates often *"claim they're good with MATLAB… but once in the company, we use a different software and they refuse to adapt"* (P5). These foundational technical deficiencies should be interpreted alongside the broader pattern of methodological weaknesses reported by experts particularly regarding difficulties in systematic troubleshooting, evidence based judgment, structured task execution, and learning agility in real production settings. In highly automated manufacturing, technical knowledge is necessary but only becomes meaningful through methodological practice where engineers must validate assumptions, diagnose root causes, adapt to unfamiliar tools, and justify decisions under strict safety, downtime, and quality constraints. Accordingly, the findings suggest a coupled competency issue in which basic technical literacy and methodological competence interact, athough the hard to fill status of these roles is driven primarily by limited methodological readiness to perform reliably in complex automation intensive environments. Such findings reflect a lack of learning agility and adaptability which are competencies increasingly emphasized in global manufacturing frameworks. This aligns with Moo and Da Wan (2023) who reported that Malaysian graduates often lack the practical technical skills expected by employers and Phang et al. (2025) who found that adaptability to new tools and processes remains one of the weakest employability attributes among engineering graduates. At the global level, the World Economic Forum (2023) highlighted learning agility as a critical skill for Industry 4.0 noting that graduates who cannot adjust to new technologies or methodologies risk being left behind in sectors where the pace of innovation is relentless.

Beyond technical and cognitive challenges, the study also revealed behavioural and attitudinal issues affecting graduates' workplace readiness. Participants described graduates as passive, overly dependent on senior engineers, and reluctant to take responsibility due to fear of making mistakes. One expert observed that *"they just wait for instructions from senior engineers"* (P3), while another noted that *"some are too afraid to take responsibility in case they make a wrong decision"* (P1). Low initiative and poor mental resilience were also highlighted, with P5 commenting that *"some just don't want to put in extra effort... they just say, 'I don't know.'"*

These behavioural gaps align with Omar et al. (2023), who found that career adaptability and resilience are critical predictors of employability among Malaysian engineering graduates, and with national survey evidence from the Ministry of Higher Education (2023), which reported persistent concerns about low initiative and confidence among graduates. At the global level, the OECD (2025) emphasised that resilience, adaptability, and lifelong learning are essential behavioural competencies in automation intensive environments, underscoring the urgency of addressing these gaps.

Across these themes, the nine issues consistently manifested as weak problem solving, lack of critical thinking, unsystematic task execution, limited project management, difficulty applying theory, low technical proficiency, overdependence on supervision, weak mental resilience, and insufficient industrial exposure, indicating an integrated methodological competency gap. Taken together, the findings confirm that the challenges faced by robotic engineering technology graduates in Malaysia's automotive manufacturing industry extend well beyond technical knowledge deficits. Instead, they reflect a systemic gap in methodological competency encompassing how graduates analyse problems, make decisions, manage tasks, adapt to tools, and behave professionally in complex industrial settings.

Addressing these gaps requires a shift in how methodological competency is assessed in undergraduate education. In this study, methodological competency is reflected in observable practices such as problem framing and root cause reasoning, evidence based justification of decisions, systematic execution and documentation, anticipatory risk or constraint consideration, and learning agility when facing unfamiliar tools. Beyond traditional written examinations, these competencies can be evaluated using performance based and authentic assessment approaches that capture how students analyse problems and execute tasks systematically. Suitable mechanisms include scenario based troubleshooting cases requiring root cause reasoning, simulation or digital twin tasks where students interpret process data and propose parameter adjustments, and project lifecycle artefacts such as planning documents or risk registers to assess project discipline. Furthermore, structured decision logs and industry aligned rubrics used during industrial training can help evaluate systematic work habits and professional independence. These assessment strategies align with the study findings by evaluating methodological competence as observable practice rather than purely declarative knowledge (Rawboon et al., 2021; Zhan et al., 2025).

Although this study focuses on robotic engineering technology graduates in automotive manufacturing, several identified gaps such as weak problem solving and low adaptability are consistent with broader employability concerns reported across engineering graduates in Malaysia (Moo & Da Wan, 2023; Phang et al., 2025). However, robotics and automation roles in automotive settings may amplify these gaps due to higher system integration complexity and the high operational costs of downtime. These insights provide strong empirical support for national workforce concerns regarding hard to fill engineering roles and highlight the need for targeted interventions that prioritise methodological competency development alongside technical training.

Future studies should test whether these competency issues differ by program type or discipline using comparative qualitative designs involving employers and graduates to ensure that curricula and industrial training frameworks effectively prepare graduates for the demands of highly automated automotive manufacturing environments.

Importantly, while employability studies across Malaysian engineering cohorts frequently report generic competency deficits such as weak analytical reasoning, adaptability, and decision making, the findings of this study suggest that robotics and automation roles tend to magnify these weaknesses due to the tightly coupled nature of production systems. In highly automated automotive environments, engineering tasks are embedded within interconnected mechanical, digital, and control subsystems, where minor diagnostic or decision errors can escalate into safety risks, quality deviations, or costly production downtime. As a result, methodological weaknesses become more visible and consequential in robotics oriented roles compared to less automation intensive engineering positions (Karwowski et al., 2025; World Economic Forum, 2023). However, this interpretation should be treated as tentative given the limited sample and the sector-specific nature of the study. Nevertheless, determining whether these gaps are unique to robotic engineering technology programs or represent a broader engineering education challenge requires comparative investigations across disciplines and qualification pathways, incorporating perspectives from employers, graduates, and curriculum stakeholders.

CONCLUSION

This study provides empirical validation of national workforce concerns by examining methodological competency issues among robotic engineering technology graduates in Malaysia's automotive manufacturing industry. Nine interrelated issues were identified, confirming that current educational models inadequately prepare graduates for the demands of highly automated production environments. The findings suggest that resolving the "hard-to-fill" status of robotic engineering technologist roles requires more than simply expanding technical content. Higher education institutions must prioritize methodological competencies, including critical thinking, complex problem solving, project management, adaptability, and professional resilience. To achieve this, industrial training programs should be restructured to ensure meaningful exposure to real production systems, while sustained university-industry collaboration remains essential to maintain curriculum relevance.

However, the scope of these findings must be considered within the context of the study's design. This research is based on in depth insights from five industry experts across three automotive manufacturers; thus, the results are intended for analytical generalization and contextual transferability rather than a statistical representation of the entire Malaysian automotive sector. The perspectives captured primarily reflect automation intensive production contexts and may not fully reflect the diversity of practices across SMEs and supply chain firms, such as Tier 1 or 2 vendors, where role scopes, tooling, and training arrangements often differ. Additionally, because the study relies on expert and supervisor perceptions, it does not incorporate the graduates' own self reported experiences or their personal assessments of the transition from academia to industry.

To address these limitations, future research should triangulate evidence by interviewing recent graduates to understand perceived barriers to applying theoretical knowledge, specifically regarding curriculum enactment, industrial training quality, onboarding processes, and workplace learning culture. Expanding the participant pool to include SMEs across the automotive supply chain is also necessary to provide a more comprehensive sectoral view. Ultimately, the development and validation of a structured methodological competency framework tailored to robotics-based manufacturing roles remains a priority. Such a framework can guide curriculum design, training initiatives, and competency assessment, narrowing the education-to-employment gap and supporting Malaysia's advanced manufacturing agenda.

REFERENCE

1. Ba Qatyan, A., & Bin, Z. (2022, 10/19). Toward the Adoption of Industry 4.0: The Skills of the Civil Engineering Workforce Relevant to the Fourth Industrial Revolution. International Journal of Academic Research in Business and Social Sciences, 12. https://doi.org/10.6007/IJARBSS/v12-i10/15368
2. Barbieri, L., Mussida, C., Piva, M., & Vivarelli, M. (2019). Testing the employment impact of automation, robots and AI: a survey and some methodological issues.

3. Beagon, U., & Bowe, B. (2023, 09/27). Understanding professional skills in engineering education: A phenomenographic study of faculty conceptions. Journal of Engineering Education, 112, 1109-1144. https://doi.org/10.1002/jee.20556
4. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative research in psychology, 3(2), 77-101.
5. Cain, K., & Coldwell-Neilson, J. (2024). Digital fluency–a dynamic capability continuum. Australasian Journal of Educational Technology, 40(1), 42-56. https://ajet.org.au/index.php/AJET/article/view/8363
6. Cao, H., & Choudhary, P. (2023). Agile Transformation in the Automotive Industry: A Case Study of Volvo Trucks. https://www.diva-portal.org/smash/get/diva2:1774050/FULLTEXT01.pdf
7. Caton, A., Bradshaw-Ward, D., Kinshuk, K., & Savenye, W. (2022). Future directions for digital literacy fluency using cognitive flexibility research: A review of selected digital literacy paradigms and theoretical frameworks. Journal of Learning for Development, 9(3), 381-393. https://jl4d.org/index.php/ejl4d/article/view/818/851
8. Gen, T. Z., Kuen, D. C. Y., Rao, V. M., & Lima-de-Oliveira, R. (2025). Industry 4.0 technology adoption in Malaysian manufacturing: strategies for enhancing competitiveness.
9. Hadibarata, T., Hidayat, T., & Kwabena, J. (2023). Problem based learning in engineering course in Malaysia. Acta Pedagogia Asiana, 2(2), 95-105.
10. Islam, M. A. (2022, 2022/01/01/). Industry 4.0: Skill set for employability. Social Sciences & Humanities Open, 6(1), 100280. https://doi.org/https://doi.org/10.1016/j.ssaho.2022.100280
11. Ismaili, B., Bakkali, S., & Benriyene, S. (2025). The Employability of Engineers in the Era of Industry 4.0. Engineering Proceedings, 97(1), 35.
12. Ito, A. (2023). Root cause analysis for resilient production systems Chalmers Tekniska Hogskola (Sweden)]. https://research.chalmers.se/publication/535407/file/535407_Fulltext.pdf
13. Jery, T., Ma'rof, A. A., & Rosnon, M. R. (2024, 12/07). The Impact of Industrial Training on Career Challenges and Motivations among Malaysian Public Universities Students. International Journal of Academic Research in Business and Social Sciences, 14. https://doi.org/10.6007/IJARBSS/v14i12/24000
14. Jessica Anne, A., Alexander, P., & Punadi, R. P. (2025). Adoption of Artificial Intelligent Driven Smart Inspection System at H Automotive Manufacturing Industry in Selangor.
15. Karwowski, W., Salvendy, G., Albert, L., Kim, W., Denton, B., Dessouky, M., Dolgui, A., Duffy, V., Kumara, S., Li, J., Madni, A., McGinnis, L., Rouse, W., Shamma, J., Shen, M., Simchi-levi, D., Swann,
16. J., & Tiwari, M. (2025, 01/17). Grand challenges in industrial and systems engineering. International Journal of Production Research, 63, 1-46. https://doi.org/10.1080/00207543.2024.2432463
17. Khan, S. H., & Mourad, A. H. I. (2025, 2025/12/31). Integrating Industry 4.0 in engineering education: implementation patterns, pedagogical strategies, and industry alignment. Cogent Education, 12(1), 2588010. https://doi.org/10.1080/2331186X.2025.2588010
18. Lijie, H., Mat Yusoff, S., & Mohamad Marzaini, A. F. (2025). Influence of AI-driven educational tools on critical thinking dispositions among university students in Malaysia: a study of key factors and correlations. Education and Information Technologies, 30(6), 8029-8053.
19. Moo, K. H., & Da Wan, C. (2023). Graduate Employability in Malaysia: Unpacking the Concept, Policy and Practices. IIUM Journal of Educational Studies, 11(2), 3-25. https://journals.iium.edu.my/ijes/index.php/iejs/article/view/471
20. Muhamad, N., Ab Gani, N., Uyob, S., & Saruji, S. C. (2019). Students' Critical Thinking Skills and Awareness of Industry 4.0: A Preliminary Study. Journal of Human Development and Communication (JoHDeC), 8, 13-22.
21. Nikolić, N., Djapan, M., Damjanović, A., Radenković, M., & Mačužić, I. (2023). Implementation Of Robotics For Lean Manufacturing Improvement. International Journal for Quality Research, 17(4). http://ijqr.net/journal/v17-n4/10.pdf
22. Nioata, A., Țăpirdea, A., Chivu, O. R., Feier, A., Enache, I. C., Gheorghe, M., & Borda, C. (2025). Workplace Safety in Industry 4.0 and Beyond: A Case Study on Risk Reduction Through Smart Manufacturing Systems in the Automotive Sector. Safety, 11(2), 50.
23. OECD. (2025). OECD Skills Outlook 2025: Building the Skills of the 21st Century for All. https://www.oecd.org/en/publications/oecd-skills-outlook-2025_26163cd3-en.html

24. Omar, M. K., Romli, A. H., Azeem, N., & Zakaria, A. (2023). Relationship between career adaptability and employability skills: Towards engineering graduates career development. International Journal of Academic Research in Business and Social Sciences, 13(12), 5026-5039.
25. Osman, I., Ibrahim, A., Mohd, I. H., Hashim, M. J. M., & Ahmad, N. N. (2025). Graduate soft skills and employability in Malaysia: The view of employers from different manufacturing companies. Social and Management Research Journal, 22(1), 1-16.
26. Petropoulos, F., Akkermans, H., Aksin, O. Z., Ali, I., Babai, M. Z., Barbosa-Povoa, A., ... & Zheng, T. (2026). Operations & supply chain management: principles and practice. International journal of production research, 64(1), 330-513.Phang, F., Zakaria, Z., Addi, M., & Mohd-Yusof, K. (2025, 11/30). Graduate Employability among Engineering Graduates in Malaysian Public Universities. Jurnal Kejuruteraan, 37, 3903-3910. https://doi.org/10.17576/jkukm-2025-37(8)-20
27. Radzi, N. M., & Ghani, M. F. A. (2021). The design of effective school enterprise programme for vocational colleges in malaysia: An application of fuzzy delphi method. MOJEM: Malaysian Online Journal of Educational Management, 9(4), 73-96.
28. Rasib, A., Abdullah, R., Wahyono, F., & Ramli, M. (2025). Enhancing manufacturing efficiency: A case study on automotive assembly line balancing techniques for improving production capacity. Journal of Engineering Science and Technology, 20(2), 427-441.
29. Rawboon, K., Yamazaki, A. K., Klomklieng, W., & Thanomsub, W. (2021). Future competencies for three demanding careers of industry 4.0: Robotics engineers, data scientists, and food designers. The Journal of Competency-Based Education, 6(2), e01253.
30. Rikala, P., Braun, G., Järvinen, M., Stahre, J., & Hämäläinen, R. (2024, 2024/04/01/). Understanding and measuring skill gaps in Industry 4.0 — A review. Technological Forecasting and Social Change, 201, 123206. https://doi.org/https://doi.org/10.1016/j.techfore.2024.123206
31. Saari, M. Y., Hashim, M. Z. L., Adzman, A. I., Mokhyi, N. A., & Yazid, M. A. N. A.-F. M. (2025). The "Gaji Cukup Makan" Economy – When Higher Education Becomes An Economics Risk. https://euera.org/the-gaji-cukup-makan-economy-when-higher-education-becomes-an-economics-risk/
32. Saleh, H., & Lamsali, H. (2019). Engineering skills: Employer satisfaction among Malaysian graduate engineer. International Journal of Electrical Engineering and Applied Sciences, 2(2), 63-68.
33. Sherif, Z., & Salonitis, K. (2025, 2025/11/01). A systematic review of decision tools for process selection and performance improvement in manufacturing. The International Journal of Advanced Manufacturing Technology, 141(3), 1113-1141. https://doi.org/10.1007/s00170-025-16806-y
34. Su, M., Ma, L., Zhang, D., Yunusa-Kaltungo, A., & Cheung, C. (2025, 01/26). Exploring Benefits and Concerns of Incorporating Digital Tools into Engineering Education. European Journal of Education and Pedagogy, 6(1), 45-51. https://doi.org/10.24018/ejedu.2025.6.1.909
35. Talent Corporation Malaysia, A., & Committee. (2020). Critical Occupations List 2019/2020 Occupation
Report. https://www.talentcorp.com.my/clients/TalentCorp_2016_7A6571AE-D9D0-4175-B35D-
36. 99EC514F2D24/contentms/img/TalentCorp_CriticalOccupationsList_FullList_2019-2020_V2.pdf
37. Vo, B., Kongar, E., & Suárez-Barraza, M. F. (2020). Root-cause problem solving in an Industry 4.0 context. IEEE Engineering Management Review, 48(1), 48-56.
https://www.scribd.com/document/556252190/Root-Cause-Problem-Solving-in-an-Industry-4-0Context
38. Wei, L. C., & Yew, M. P. (2024). The Overeducation Dilemma: Graduate Skill Mismatch In Malaysia's Labour Market. International Journal of Business, Economics and Law, 33(1), 60-66. https://ijbel.com/wp-content/uploads/2024/12/IJBEL31_34.pdf
39. World Economic Forum. (2023). The future of jobs report 2023.
https://www.weforum.org/reports/thefuture-of-jobs-report-2023
40. Zhan, S., Chapman, E., Valentine, A., & Male, S. (2025). Enhancing the measurement of employability in engineering: insights from a systematic literature review. European Journal of Engineering Education, 1-20.