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RESEARCH ARTICLE

Engineering Excellence in the Digital Age: Integrating Technical Expertise with Industry 4.0 Competencies

Irmohizam Ibrahim[1], Norhasni Zainal Abiddin[2*]

[1,2]National Defence University of Malaysia, Malaysia

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***Corresponding Author:**

norhasni@upnm.edu.my

ABSTRACT

The rapid advancement of Industry 4.0 has fundamentally transformed engineering work environments, demanding a sophisticated integration of technical expertise, digital competencies, and interpersonal skills. While technical proficiency remains foundational, contemporary engineering performance is increasingly determined by an engineer's ability to navigate digital transformation, cross-cultural collaboration, and virtual team dynamics. This study examines the evolving nature of engineering performance in the digital age, focusing on the intersection of technical knowledge, digital literacy, and soft skills within globally distributed teams. The research explores how engineering professionals must adapt to new technological frameworks while maintaining effective interpersonal relationships in virtual environments. Through comprehensive analysis of emerging workplace dynamics, this article investigates the critical success factors for engineering performance in an era of digital transformation, including the ability to work across cultural boundaries, manage virtual teams, and drive innovation in remote settings. The findings contribute to the development of more effective digital transformation strategies and training programs customized for the modern engineering workforce. These insights are particularly valuable for organizations seeking to enhance their engineering teams' effectiveness in the digital age and for professionals aiming to advance their careers in an increasingly globalized and technology-driven marketplace. The study concludes with practical recommendations for implementing digital transformation initiatives, developing global team capabilities, and fostering an innovation culture that supports continuous learning and adaptation to technological change in the engineering sector.

INTRODUCTION

The rise of Industry 4.0 has greatly changed the face of engineering as it requires a synergy between digital technologies, automation and interconnected systems (Rojko, 2017). With manufacturing automation climbing to smarter and serialized, Fourth Industrial Revolution (4IR) is revolutionizing the way that engineers must adapt their work including smart factories, Artificial Intelligence (AI) and Internet of Things (IoT). Engineers need to develop their technical expertise and interpersonal skills, as it is increasingly recognized that in the programmable age they will work best when combining hard and soft competencies (Frank et al., 2019).

As this digital world progresses, the makeup of engineering teams has moved into a more global and virtually distributed format. Cross cultural collaboration and remote work are no longer exceptions, yet working at far distances divergent time, cultures nuances as well different forms of virtual communication platforms like Slacks and Webex have become an unspoken common place engineers must tussle with (Kaushik & Raman, 2015). With this paradigm shift the demand of soft skills has escalated which Maniscalco (2010) defines as a set of characteristics like communications, empathy and flexibility. Similarly, Devedzic et al. (2018) stresses on the importance of this interpersonal skills in promoting team performance and project results in virtual settings.

Digital technologies which emphasize the collaboration of engineers and integrating their practices has created challengers in workforce development as well team management. Although technical expertise continues to be crucial, requires strong problem solving, creative thinking and adaptive learning skills, engineering teams are working more often across geography and culture, communication skills and cultural intelligence have become very important (Litzinger et al., 2011). For modern engineering positions, a complete collection of expertise is required beyond the knowledge-base in traditional technical areas. This is in accordance with Young (2018), who says employers are now looking for engineers capable of navigating the technical and social intricacies that come along side today's engineering challenges. This change in engineering role evolution is indicative of larger scale movement within the industry, where being technically proficient alone can be only one aspect that determines success streamlined to a successful journey from development through deployment and more but also how adroitly you improvise, collaborate and innovate into this digital emancipating world.

CONTEMPORARY CHALLENGES IN ENGINEERING PERFORMANCE

Soft skills are known to be critical, however research has suggested that many graduates and engineers have insufficient soft skill training which can lead to poor job performance, non-teamwork, management relationships with clients and career development at the early stage of their (Abiddin 2024). Since engineering roles have transformed into highly collaborative, client-facing and leadership-intensive functions of late, targeted training programs on soft skills are the need of the day. In addition, the integration of these competencies is crucial for driving employee performance which in turn brings success to an organization (Ibrahim & Abiddin, 2024; Ibrahim et al. 2017).

The demand for workers who are already high skilled has been gradually increasing, but there is little doubt that it will be basic technical skills alone that would suffice (Ismail et al. Without high level soft skill, engineers will be less competitive and productive in global open market economy nowadays (Esa et al., 2015). Engineers today have to understand that soft skills are equally and sometimes even more valuable for career progression in a global open market economy. Thus, the concern to enhance work productivity and professional efficiency of engineers has developed an increasing prominence in improving their soft skills by means of appropriate training programs (Galimullina et al., 2020).

Today, however, employers expect employees to have a combination of hard and soft skills. Dean (2017) argues that soft skills are the key facility which employers anticipate employees to show off and balance other qualities acquired throughout their study period as well through past working experiences, instead of just holding paper degrees. Also, the workforce has gotten to be more differing. For cases when an agent may travel starting with one culture then onto the next while working that being capable will speak aptitudes should show necessity. Providing the most related training combine with identify criteria for their employees, development of soft skills is dependent on an organization (Ogbodoakum, et al., 2022).

Engineering projects also require soft skills such as communication, teamwork, leadership, and problem-solving abilities as well as adaptability. These will enable good and healthy communication, are a requirement for critical thinking as well as problem-solving techniques and assist in project management making graduates employable (de Campos, de Resende & Fagundes, 2020). These are critical skills for planning projects, delivering concepts and organising resources so that desired goals can be achieved. Additionally, organization value takes them up to the founders who can talk and interact well with others as this is a human-related task which makes prospect things easier in delivering projects. Furthermore, the addition of these beneficial soft skills will help complement an engineer's resume to make you a more versatile commercial asset, which directly improves any engineers existing employability in their field.

Despite the growing awareness of soft skills in workplace, many Malaysian engineers especially among automotive industry professionals lack essential proficiency on these traits. The automotive industry is quite competitive, and engineers must be able to not only demonstrate their technical knowledge but also several soft skills that are crucial for success in the profession such as communication, teamwork; problem-solving adaptability and leadership. The challenge is that many engineers are sorely lacking in these skills and it hinders them at work for examples leading, engaging customers effectively and collaborating (Dean, 2017). Not having these soft skills is a huge performance gap that prevents engineers and will continue to stop the industry from coming out on top. Those are all skills that atrophy over time, and either forget them or didn't have then to begin with and nothing halts the functionality in automotive product development like a non-moving cross-functional team.

This absence of people skills brings about inter departmental clashes just as coordination issues, eventually upsetting the dynamic cycle and effective conveyance arranges (Iosifidou, 2024). Even though it has been widely recognized that soft skills play a substantive role in work performance, less attention is being paid to the association between specific training programs and related skill development or the impact of prevailing workplace condition on their use (Talha & Abiddin, 2024). Studying this gap is necessary to develop specialized training programs that teach engineers the soft skills they need for an updated job climate, which supports their work performance and corrects current industry deficits.

LITERATURE REVIEW

Work Performance Framework

Performance frameworks have transitioned from purely human-defined success goals to a view which incorporates challenging technological possibilities and enduring truths about organizational performance against the backdrop of digital transformation. Contemporary performance models understand that personal contribution goes beyond the jobs associated with you as roles and function in dynamic digital are changing consistently! Instead, these new approaches require that performance is now partly dependent on a person's dexterity in using digital platforms, virtual collaboration tools and their aptitude for operating within cross-cultural team dynamics (Cascio & Montealegre 2016). Because of these changes in technology and globalization, the traditional notion of job performance which used to basically come down to doing your tasks effectively and following a pre-determined role has changed quite a bit.

This is reflected in recent research claiming that performance in digital workspaces should not be limited to static job descriptions but also reflect the dynamic era of modern workplace (Schwarzmuller et al., 2018). This change, in part, is a response to an increasing awareness of the needs for adaptability and digital literacy as well as cross-functional collaboration important areas that will drive better performance (Abiddin et al., 2022). According to Colbert et al. (2016), digital competencies have become an increasing necessity in the job performance within today's

organizations person that cannot accomplish these resulting both traditional tasks and their affiliated responsibilities would not perform as efficiently or effectively on the small scales. As such, performance measurement has also progressed from a task-based evaluation format to include digital acumen metrics that support virtual team work and innovation capabilities (Abdul Aziz & Abiddin, 2024; Harteis, 2018). It is a wider lens on work performance where success in the modern organization results from these technical skills and digital competencies, coupled with adaptive behaviors that are attuned to evolving changes within technology landscapes.

Table 1 Frameworks Addressing Aspects of the Performance Domain

Authors	**Aspect**
Campbell et al., 1993	- Job-specific task proficiency - Non-job-specific task proficiency - Written and oral communication proficiency - Demonstrating effort - Maintaining personal discipline - Facilitating peer and team performance - Supervision and leadership - Management and administration
Borman & Motowidlo, 1993	- Task performance - Contextual performance
Welbourne et al., 1998	- Job role behaviour - Career role behaviour - Innovator role behaviour - Team role behaviour - Organization role behaviour
Podsakoff et al., 2000	- Helping behaviour - Sportsmanship - Organizational loyalty - Organizational compliance - Individual initiative - Civic virtue - Self-development
Pulakos et al., 2000	Adaptivity
Frese & Fay, 2001	Proactivity
Crant, 2000	- General proactive behaviour - Context-specific proactive behaviour
Johnson, 2003	- Task performance - Citizenship performance - Adaptive performance
Parker et al., 2006	Proactive work behaviour

Based on Table 1, changes in performance frameworks which evolve through the 1990s and become more mature by early 2000 demonstrates an evolution of understanding workplace effectiveness transformed from individual to a much complex organizational environment. Initial frameworks like Campbell et al. (1993) model to develop the definitive state taxonomies including both technical and interpersonal but number of researches followed for example Borman & Motowidlo, 1993; Welbourne et. al (1998) introduced similar but more complex perspectives that focus on differentiation in core task performance and wider organizational contribution. This development in performance understanding reflects the fact that conventional job-specific competencies are not sufficient such as behaviors, related to organisational success under dynamic conditions (Tims et al., 2012) can be found broadly across all levels.

Especially as we move into the 'ones and twos' along language, through to 2000 onwards, many of these later frameworks in table have begun to stress adaptation adaptability changed proactively

expressing behaviour is increasingly essential for professionals nowadays. Podsakoff et al. (2000) comprehensive model of citizenship behaviors, with that offered by Pulakos et al. The (2000) attention to the adaptive comparative work of Frese & Fay (1991), and Parker et al. Proactivity (2006) argues that performance can no longer be expected of employees, where they simply show up and do what is required. The intention of the author is to relate requests for flexibility and innovation from organizations in today's digital transformation times, which fits well with these latest developments in performance frameworks (Griffin & Parker 2018).

Table 2 Models of Work Performance Behaviours

Individual Work Role Behaviours	**Proficiency**	**Adaptivity**	**Proactivity**
Individual Task	Ensure core task are completed properly	Adjust to new equipment, processes or procedure in core tasks	Initiates better way of doing core tasks
Team Member	Coordinates work with team members	Responds constructively to team changes (e.g., new members)	Develops new methods to help the team perform better
Organization Member	Talks about the organization in positive ways	Copes with changes in the way the organization operates	Makes suggestion to improve the overall efficiency of the organization

Source: Griffin et al. (2007)

Referring to Table 2, the matrix of work performance behaviors provides an integrated approach to assessing how individuals contribute at the individual, team and organizational levels within a digital transformation context with global virtual teams. At the level of individual tasks, mastery now means more than just executing traditional tasks but also includes digital tool usage and virtual workflow proficiency. At this level, adaptivity has grown majorly as the scope of technologies is magnifying and engineers have to be more responsive towards artificial intelligence aspect in their product feature orspecification releases with automation. Proactivity at the individual level in involves individuals being not merely responsive to enhancing core tasks but also proactive in identifying opportunities for digital innovation and process automation (Schwarzmuller et al., 2018).

With the rise of globally distributed engineering teams, the team member dimension has become increasingly important. Team coordination which was earlier a straightforward, now demands the command over virtual collaboration tools, cross-cultural communication platforms & digital project management systems. Fast forward to today and team adaptivity has expanded to work that crosses global time zones, different cultural norms with respect to how we show up at work or interact with each other, solve problems, create together, be part of a group and the process of quickly adapting our approach when working within virtual teams where they may change on almost a monthly basis. It is likely that proactive team behavior includes efforts in virtual collaboration innovation, recommendations for digital tools to aid team performance and the development of solutions to challenges academic teams experience as a result of working remotely (Harteis & Goller, 2014).

At the organizational level also can be observe how these behaviours have been extended to digital transformation initiatives and operating globally. It is essential for the profession to reach a new milestone through building organizational member skills more from digital culture promotion and technology advance support. In the field of adaptivity, this means control over organizational change driven by digital transformation; in the realm of proactivity it refers to participating in generating a digital strategy and proposing innovations that allow organizations to be competitive on global

markets. The second layer the world of work reflects the changes in performance behaviours associated with modern engineering organizations working in a digital, interconnected globe (Van der Heijden et al., 2019).

Social Cognitive Theory

Social Cognitive Theory by Bandura (2018) deals with learning behaviors in the workplace through observation, imitation, and modeling. It emphasizes that learning occurs through observing others, a process known as observational learning or modeling (Obiyo, 2023). According to Bandura (2018), individuals can acquire new behaviors by observing and imitating others in their environment. This Social Cognitive Theory provides valuable insights into how employees acquire soft skills in a professional setting. The theory highlights observational learning, modeling, and reinforcement as essential processes that enhance employees' abilities, particularly in roles involving high levels of interpersonal interaction, such as engineering. This theory explains how individuals acquire behaviors through active observation of others, which is fundamental for understanding how soft skills are learned.

In this research, this theory is applied to explain how engineers develop interpersonal and other soft skills through observation and interaction with colleagues and mentors in the workplace or during training activities in soft skills development programs. It underscores the importance of modeling, imitation, and observational learning as key mechanisms for acquiring and implementing new skills (Abiddin, 2007).

Engineering Performance in The Digital Era: A Comparative Analysis of ASEAN Industrial Powerhouses

Engineers in ASEAN nations are seeing different approaches through the digitalization of engineering practices, with two regional heavyweights standing out. As the technology hub in the region, Singapore has been at forefront of digital engineering excellence with 78% of its firms adopting full scale Digital Transformation (DT) strategies amongst all APAC's countries (Tan & Lee, 2023). Malaysia, by comparison has an adoption rate of 45% in automotive and manufacturing sectors, whereas Thailand-The Detroit of Asia as it's called shows a utilization at approximately 52% followed up with their booming Automotive engineering sector. Indonesia: Indonesia, which has significant manufacturing presence, is well on its way to a DT rate of 38%, driven largely by broad commercial or industrial automation (ASEAN Digital Integration Index, 2023).

This inadequate performance in engineering across these nations comes down to different levels of technological infrastructure and human capital development. The answer lies in Singapore's massive investment across digital infrastructure and engineering talent development with 2.8% of its gross domestic product (GDP) spent on research & development While Thailand has progressed towards becoming a specialized automotive engineering hub, it still invests significant resources in robotics and automation training programs. Vietnam, an emerging manufacturing hub and electronics manufacturer in particular where 40% year-on-year automation usage was adopted (Nguyen et al., 2024). Project teams engineered from Singapore often report higher effectiveness but still moderate due to insufficiency of basic digital literacy, conversational English fluency and comfort with continuous cross-border communication. Engineers in Malaysia are used to managing project among different cultures and they view diversity as a strategic advantage. Thailand teams excel in the production optimization and quality control scenarios, while Vietnamese engineering groups demonstrate accuracy especially in rapid prototyping and agile manufacturing processes (ASEAN Engineering Federation 2024).

What then will determine the future path of engineering performance in ASEAN? Is it just digital infrastructure development, talent mobility within the region or is also dependent on cross-border innovation hubs being created. Indonesia and the Philippines rapidly modernizing digital systems

with massive investments in 5G infrastructure, cloud facilities The ASEAN Engineering Innovation Centre in Cyberjaya which was set up most recently, serves as a step forward for Malaysia to build relationships and share resources on the regional level (World Economic Forum, 2023).

Modern Challenges and Future Perspectives in Engineering

The Modern Challenges in Engineering

Industry 4.0 has significantly shifted the way engineering work takes place at its core forcing traditional engineering practices, which were highly manual for more than century, to become connected and automated beyond belief. More than 65% of the engineering enterprises around the world have announced or are announcing a dramatic change in their mode of production because they now rely on industry 4.0. As a result, it involved linking traditional engineering activities with Cyber-Physical Systems (CPS), Internet of Things (IoT) platforms and machine learning solutions on an everyday basis. With an increasing need for real-time data analysis,predictive maintenance and smart manufacturing systems now full de facto requisites of the engineer's environment.

In the last few years, Artificial Intelligence (AI) and automation have had a huge impact on performance metrics and expectations of engineering roles. AI designs their workflow in a way where they can move from the rudimentary computations and standard design iterations, leaving them with an opportunity to work at another level. According to the Institute of Engineering Technology (2024) AI-assisted engineering tools solved design errors by 40%, but it gives birth to complex issues with quality control and system supervision. This evolution has in turn pushed for a reorganization of engineering workflows, with human skillsets focused more on problem-solving and innovation than repetitive task management.

Formerly conventional in place of business relations and undertaking control were modified as effects to the post-pandemic workplace. The capability of remote work is now a must, 78% engineering firms have embraced hybrid model (McKinsey Global Institute, 2023). This switchover has initiated the need of advanced virtual collaboration application and digital twin technology for syncing project continuity and team coordination. Engineers now need to master a set of soft skills like virtual team leadership, digital communication and remote project management in order to continue producing work that is accurate, efficient and innovative.

In the engineering industry, digital transformation challenges are some of the most formidable with security concerns, data integration issues and a host of systems that are in desperate need to modernization. Organizations need to protect their intellectual property (IP) whilst simultaneously fostering frictionless collaboration across dispersed teams. Recent industry surveys have borne this out, with 55% of engineering teams citing “very significant” barriers to implementing new digital platforms alongside legacy lines and little more than two-thirds experiencing data alignment problems between technologies.

Future-Focused Elements in Engineering

There has been a rapid change in the skillsets required for engineers of the future and interdisciplinary skills are being seen as a necessary complement. Engineers in 2030 must meld traditional engineering with next level digital skills at the far end of that spectrum which involves AI development, quantum computing applications and sustainable design principles. In the World Economic Forum (2023), has said that 65% of engineering roles and another 75 percent will require aptitude in sustainable technologies, green-engineering practices and advanced data analytics capabilities.

For example, new engineering positions are crossing the boundaries of several disciplines and technologies. Roles such as Digital Twin Architects, Sustainable Systems Engineers which are new

positions and job titles like AI Integration Specialists are on a rise. These positions contain a rare mix of technical know-how, business savvy and environmental awareness. The Bureau of Labor Statistics estimates that hybrid engineering roles combining traditional, emerging disciplines and related careers will increase 45% over the next decade.

In the coming years, challenges for industries will revolve around sustainability and resource optimization as well as technological incorporation. Engineers must grapple with even more stringent pressures to produce new carbon-neutral solutions that keep them competitive in a global market. The 2023 Global Engineering Sustainability Report also found nearly four out of five large engineering firms now include environmental impact assessments in their regular procedures, emphasizing the growing presence of climate change adaptation and mitigation strategies within engineering efforts (UNESCO, 2023). Also, the ever-growing number of connected systems poses a challenge for keeping those systems safe and cybersecurity remains on industry wide agony list.

Workplace trends point to more flexible, technology powered engineering environments in the future. It is expected engineering design and collaboration tools have the potential to become standard in Virtual Reality (VR) and Augmented Reality (AR), with an estimated 70% of engineering work will involve Mixed Extended Mixed Reality (MEMR). Integrating block chain technology for project validation and smart contracts will also trigger a major shift in the quality management of engineering projects.

CONCLUSION

The modern era has assured the global transformation of engineering practices along with bringing formal requirements to achieve successful performance in this realm. The study has occurred, revealing that although technical proficiency is important, the skills to operate digital technology thrive from culture and innovation through remote connectivity are just as necessary for successful careers in engineering. Our findings illustrate the fact that engineering development must consider more than just technical training but also digital literacy, cross-cultural competencies, virtual team management skills. In addition, the study highlights how essential it has become to go digital in a way that not only allows engineering teams to evolve technologically but also grow in human terms on transforming strategies.

In the future, as Industry 4.0 technologies continue to evolve, engineering staff will need veritably adaptive and digitally empowered professionals. Key to overcoming year on year, a study of industry-wide challenges and opportunities suggests that organizations with the most innovative cultures are much more likely to trouble in engineering will be those that create forward-looking systems for global team development and textile production. Results also provide insight into how the integration of digital tools, global collaborations and innovative skills can improve engineering performance. The focus of this survey looks set to be all the more important in an engineering space rapidly changing: Balancing technical excellence with digital transformation competencies, not only for individual career progression but also a key factor instrumental to organization success on global scale landscape.

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