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Towards an IoT Competency Model for Polytechnic Lecturers: A Preliminary Study

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Abstract

The rapid integration of the Internet of Things (IoT) into technical education and industry demands lecturers with adequate knowledge and skills to prepare students for future workforce needs. However, Polytechnic lecturers, particularly in the field of Mechanical Engineering (Automotive), continue to face challenges in applying IoT effectively within teaching and workplace contexts. This preliminary study aimed to explore lecturers' perceptions of IoT competency, identify challenges in classroom and workplace application, and examine the necessity of a structured IoT competency framework for Polytechnic educators. A qualitative research design was employed using semi-structured interviews with three Polytechnic lecturers. Thematic analysis revealed that while lecturers acknowledged the importance of IoT in enhancing teaching relevance and industry alignment, significant gaps exist in terms of knowledge, confidence, and availability of supporting frameworks or training modules. Respondents emphasized the need for a structured competency model to guide IoT integration in both teaching and industry practices. The findings highlight critical implications for curriculum development, professional training, and policy initiatives to strengthen IoT capacity among Polytechnic lecturers. This study provides an early foundation for developing an IoT competency model that can inform broader implementation in Malaysia's Technical and Vocational Education and Training (TVET) ecosystem.

Keyword: Internet of Things (IoT), Competency, Polytechnic Lecturers, Technical and Vocational Education and Training (TVET), Preliminary Study

Introduction

The Fourth Industrial Revolution (IR 4.0) has transformed the landscape of education and industry through the integration of advanced digital technologies, including the Internet of Things (IoT). IoT refers to the interconnection of devices, machines, and systems that communicate and exchange data to enhance efficiency, productivity, and innovation. In the context of Technical and Vocational Education and Training (TVET), IoT plays a pivotal role in equipping students with industry-relevant skills and preparing them for the demands of smart manufacturing, intelligent systems, and data-driven workplaces. Polytechnic institutions, as one of the main providers of vocational education in Malaysia, are expected to take the lead in embedding IoT competencies into teaching and learning to ensure alignment with national aspirations such as the National Policy on Industry 4.0 (Industry4WRD) and the Malaysian Education Blueprint (Higher Education) (MITI, 2018; MOE, 2015).

However, research indicates that many lecturers face challenges in integrating IoT into their instructional practices due to limited technical expertise, lack of structured training, and inadequate competency frameworks (Abdul Rahman et al., 2022; Leong & Letchumanan, 2019; Zulnaidi et al., 2020). In particular, lecturers in the field of Mechanical and Automotive Engineering, where IoT applications such as smart sensors, predictive maintenance, and connected vehicles are increasingly relevant, often report difficulties in translating industry-based IoT practices into classroom contexts (Singh et al., 2023). These challenges may the effectiveness of teaching, reduce students' readiness for Industry 4.0, and slow down the transformation agenda of TVET institutions.

Competency frameworks have been widely recognized as essential tools for guiding curriculum development, professional training, and performance evaluation (Midhat Ali et al., 2021). Yet, to date, there is limited evidence of a standardized IoT competency model tailored to the needs of Polytechnic lecturers in Malaysia. Without such a framework, efforts to enhance lecturers' readiness and strengthen the integration of IoT into teaching risk being fragmented and unsystematic.

This study was therefore conducted as a preliminary exploration to investigate Polytechnic lecturers' perceptions of IoT competency, the challenges they face in applying IoT in their teaching and professional practice, and their views on the necessity of developing a structured IoT competency model. Using semi-structured interviews with three lecturers in Mechanical and Automotive Engineering, this study seeks to provide early insights that will contribute to the design of an IoT competency framework for Polytechnic lecturers. The findings are expected to inform future curriculum planning, policy formulation, and professional development initiatives in Malaysia's TVET sector.

Literature Review

IoT in Automotive

The Internet of Things (IoT) has become one of the most transformative technologies in the automotive sector, reshaping the way vehicles are designed, manufactured, and operated. By embedding sensors, communication modules, and data processing capabilities, vehicles are now capable of interacting not only with drivers and passengers but also with other vehicles, infrastructure, and the wider digital ecosystem. This integration, often referred to as the Internet of Vehicles (IoV), enables innovations such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, which improve road safety, traffic management, and overall driving efficiency (Rahim et al., 2021; Zhang & Letaief, 2019). In this context, IoT is no longer seen as an optional enhancement but as a core technology driving the next generation of mobility solutions.

A growing body of research highlights the critical role of IoT in predictive maintenance and diagnostics. Through real-time monitoring and data analytics, vehicles can identify potential component failures before they occur, reducing downtime and maintenance costs.

This is particularly important in electric vehicles (EVs), where battery health and energy management are central to performance. AlHousrya et al. (2025) demonstrate how industrial IoT (IIoT) technologies can optimize charging behaviors, extend battery lifespan, and increase overall energy efficiency in EV fleets (AlHousrya et al., 2025). Similarly, connected sensors and communication technologies have enabled advancements in intelligent transport systems, where vehicles exchange data with surrounding environments to enhance navigation and cooperative driving (Iordache et al., 2024). These applications underscore the significance of IoT as both a technological enabler and an operational necessity in modern automotive ecosystems.

Beyond efficiency and safety, IoT is also driving innovation in user experience and vehicle autonomy. Smart vehicles now integrate features such as adaptive navigation, personalized ride settings, and advanced driver-assistance systems (ADAS), which rely on continuous data flows between sensors, cloud platforms, and decision-making algorithms. Ekanem et al. (2024) emphasize that IoT-enabled vehicles not only optimize route planning but also enhance ride comfort and passenger satisfaction, while Muthiya (2023) notes that hinder IoT integration across subsystems is ranging from braking and engine performance to infotainment that illustrates the growing complexity of connected automotive design (Ekanem et al., 2024; Muthiya et al., 2023). These developments highlight the multidisciplinary nature of IoT, combining mechanical engineering with electronics, data science, and communication technologies.

Despite its potential, the integration of IoT in automotive systems is not without challenges. Cybersecurity remains a major concern, as connected vehicles are vulnerable to remote attacks that can compromise safety-critical functions. Abreu et al. (2024) point out that in-vehicle networks such as the Controller Area Network (CAN) lack strong security mechanisms, making them susceptible to malicious interference (Abreu et al., 2024). Interoperability and standardization are also persistent issues, given the diversity of communication protocols and vendor technologies (Phan & Singh, 2023). In addition, cost and energy constraints limit the scalability of IoT features, particularly in budget vehicles or in regions where infrastructure readiness is uneven (Ismail et al., 2022). These barriers suggest that while IoT is a promising frontier in automotive technology, its successful adoption requires coordinated efforts in technical design, policy, and workforce readiness.

For educators in the field of automotive engineering, these developments present both opportunities and responsibilities. The literature suggests that IoT competency must encompass knowledge of sensors, embedded systems, networking, edge computing, data analytics, and cybersecurity. Such breadth reflects the interdisciplinary nature of IoT, where mechanical systems converge with digital and electronic domains. Preparing future engineers to thrive in this environment requires lecturers themselves to possess adequate IoT competencies, not only to teach theoretical foundations but also to guide practical applications aligned with industry practices. Without a structured competency framework, there is a risk of fragmented teaching approaches and limited alignment with real-world demands. This highlights the urgent need for research into IoT competency models for lecturers, ensuring that Polytechnic education remains relevant and responsive to the evolving automotive industry.

Competency Models

Over the past decades, competency models have gained prominence as structured tools to define, organize, and operationalize the knowledge, skills, and attitudes required in specific domains. A competency model typically offers a blueprint indicating what capabilities individuals need in order to perform effectively in a particular role or context. Its value lies in making implicit expectations explicit, guiding professional development, and aligning training programs with real-world demands. In educational and workplace settings, the adoption of competency models helps bridge the gap between theoretical learning and actual job performance, by mapping out competence in a systematic way.

Recent reviews of competency-based models underscore that many frameworks now attempt to integrate not only domain-specific technical competencies but also transversal or general competencies (such as critical thinking, communication, ethical responsibility) as integral components of professional roles. For example, Nováková et al. (2024) conducted a scoping review of competency-based models across education and training systems, highlighting how models often combine domain, pedagogical, and quality competencies in unified frameworks (Nováková et al., 2024). Similarly, Arribas-Aguila, Castaño & Martínez-Arias (2024) developed a taxonomy of general competencies, distilled from many models across occupations, that aims to serve as a reference for building new, context-sensitive competency models (Arribas-Aguila et al., 2024).

In educational research, competency models are being refined using participatory and expert-based methods such as Delphi panels. For instance, Kart & Şimşek (2024) applied three rounds of Delphi surveys with curriculum experts to define a competency model in the field of Curriculum and Instruction, arriving at a model with domains of knowledge, skills, and attitudes/values (Kart & Şimşek, 2024). Such approaches emphasize that a robust model must reflect not only technical expertise but also professional mindsets and ethical commitments inherent in the role.

Yet, studies also caution that effective implementation of competency models is not trivial. Feldman et al. (2022) discuss how competency analysis requires careful triangulation of literature review with empirical input from practitioners, and how competency definitions must be linked with educational strategies (Makulova et al., 2015). Moreover, the gap between theory and practice is well documented: models may exist on paper but fail in real settings due to poor alignment with organizational culture, resistance from stakeholders, or inadequate support systems (such as training, assessment, and feedback mechanisms). Janssens et al. (2023) highlight how even in health professions education, competency-based models require a coherent chain of design, monitoring, assessment, and reflection to become meaningful in practice (Janssens et al., 2023).

Drawing on these insights, any competency model developed for lecturers in IoT, especially in a specialized technical domain like automotive engineering, must integrate layered competencies: the foundational technical knowledge (e.g. sensors, embedded systems, networking), pedagogical translation skills (how to teach IoT in classroom or lab contexts), and meta-professional attributes (e.g. continuous learning, adaptability, ethics). The literature suggests that co-design with stakeholders, iterative validation, alignment with evaluation and feedback systems, and attention to context are essential to turn a competency model from an abstract map into a practical, usable tool in education.

Lecturers' Readiness

Lecturers' readiness to adopt new technologies is often framed not simply as possessing technical skills but as a more holistic capacity involving mindset, confidence, institutional support, and pedagogical alignment. In many transition studies, educators report being able to operate basic tools or learning management systems under necessity, such as during sudden shifts to online teaching, but they often lack strategic understanding or deeper readiness to design rich digital experiences (Junus et al., 2021). This means that surface-level comfort does not necessarily translate into sustainable integration.

Furthermore, readiness is influenced by educators' perceptions of usefulness, ease of use, and whether they feel supported in taking risks or adapting their roles. In a recent study of faculty adapting to hybrid and digital pedagogies, Alcaide-Pulido et al. (2025) found that factors such as comfort with identity disruption, willingness to deviate from traditional norms, and beliefs about equity played important roles in shaping how ready lecturers felt to engage new teaching modes (Alcaide-Pulido et al., 2025). Similarly, in investigations of artificial intelligence adoption by lecturers, Jackman et al. (2025) showed that perceived benefits and institutional facilitation (resources, training, policy) strongly mediate whether faculty move from intention to action (Jackman et al., 2025).

When the focus is on using technology more broadly (beyond IoT), multiple studies point out that lecturers are sometimes unprepared due to inadequate resources, training, or infrastructure. Munyaradzi (2024) found that lecturers' readiness to use a learning management system (LMS) was hindered by poor system design, low technical competence, and limited institutional support, suggesting that readiness is shaped as much by the environment as by the individual (Munyaradzi et al., 2024). Rahman (2024) similarly observed that instructors often report obstacles such as lack of confidence, insufficient training opportunities, and inertia in changing teaching practices when shifting toward more technology-mediated classrooms (Rahman, 2024).

In sum, the literature suggests that lecturer readiness is multifaceted: it involves not only technical ability, but also belief systems, pedagogical competence, institutional support structures, and the capacity to navigate change. In this study, with lecturers in polytechnics facing the challenge of integrating IoT in engineering subjects, these insights imply that readiness should be investigated not only in terms of self-reported skills, but also attitudes toward change, availability of enabling infrastructure and support, and alignment of institutional policies. A narrow focus on technical readiness would omit crucial barriers that may impede real adoption in the teaching context.

Methodology

This study employed a qualitative research design to capture in-depth insights into the perceptions and challenges of Polytechnic lecturers in handling IoT within their teaching practice. Qualitative inquiry is well suited for preliminary study, particularly in contexts where understanding participants lived experiences and subjective interpretations is essential (Creswell & Poth, 2016). By adopting this approach, the study aimed to generate nuanced perspectives on the need for a structured IoT competency framework rather than broad generalizations.

Participants were selected using purposive sampling to ensure that they possessed relevant expertise and experience in the field. Three lecturers from Malaysian Polytechnics were invited to participate, each with more than ten years of teaching experience in Mechanical Engineering (Automotive) as shown in Table 1. Their extended professional exposure was considered critical for providing informed reflections on both the challenges of applying IoT in teaching and the gaps in existing competency structures. Semi-structured interviews were conducted, allowing the researcher to probe key issues while giving participants the freedom to share experiences in their own words. This method has been widely recognized for its ability to elicit rich and contextually grounded data (Kallio et al., 2016).

Table 1
Research Respondents

Participant	**Polytechnic**	**Field**	**Working Experience**
Lecturer 1 (P1)	Politeknik Sultan Azlan Shah	Mechanical Engineering (Automotive)	22 years
Lecturer 2 (P2)	Politeknik Sultan Haji Ahmad Shah		15 years
Lecturer 3 (P3)	Politeknik Sultan Mizan Zainal Abidin		15 years

The interviews were carried out individually, each lasting between 15 to 20 minutes. An interview protocol was prepared in advance, covering themes such as the importance of IoT in the curriculum, the lecturers' level of competency, perceived barriers to integration, and the need for a formal competency model in Table 2. The duration was sufficient to explore these issues without causing fatigue to participants. All interviews were conducted in a professional setting to ensure comfort and confidentiality, with participants' consent obtained prior to data collection. To enhance credibility, the responses were transcribed verbatim and analyzed thematically, a process that involved identifying recurring patterns and clustering them into meaningful categories (Nowell et al., 2017). This analytic strategy provided a systematic yet flexible way of linking the data back to the study objectives.

Table 2
Themes Classification based on Research and Interview Questions

Research Question: How do Polytechnic lecturers perceive the importance, competency, challenges, and the need for an IoT competency model in Mechanical and Automotive Engineering education?		
Themes	**Sub-Themes**	**List of Interview Questions**
1. Importance of IoT	Relevance in teaching and workplace	1. Is the Internet of Things (IoT) important in today's classroom/work? 2. Is it important for a polytechnic lecturer to master the Internet of Things (IoT) in the field of Mechanical Engineering (Automotive)?
2. Challenges	Problems faced in IoT integration	3. Are there any problems in using the Internet of Things (IoT) in class/work? 4. How do you solve this problem in the work process?
3. Competency	Self-perceived competency	5. Are you considered 'competent' in using IoT in class/work?
4. Institutional Support	Availability of framework, SOP, or training	6. Are there any models/frameworks/SOPs regarding competencies provided to master IoT in industry/polytechnics?
5. Future Needs	Necessity of a competency model	7. Is there a need for a study on the development of an IoT competency model for lecturers at polytechnics in the field of Mechanical Engineering (Automotive)?

The methodological decisions in this study align with practices in recent educational research, where preliminary studies often use small but focused samples to surface key insights before larger-scale validation (Guest et al., 2020; Mohd Ahyan et al., 2023). While the number of participants was limited, the depth of expertise of the lecturers and the focused nature of the questions offered valuable evidence to inform the early development of an IoT competency framework tailored for Polytechnic education in Malaysia.

Findings and Discussion

Findings

Table 3

Themes, Sub-Themes, and Supporting Quotes from Polytechnic Lecturers

Theme	Sub-Theme	Findings	Supporting Quotes
Importance of IoT	Relevance in teaching and Industry	Lecturers agree IoT is crucial for automotive, especially in diagnostics, vehicle servicing, and access to global resources.	"It is important, especially in the automotive field… everything is on the internet" (P2) "It is also important because it is important for teaching and learning… it can be integrated into the subject" (P3)
Challenges	Infrastructure and curriculum limitations	Internet instability and weak facilities hinder IoT use. IoT is absent from formal curriculum, limited to projects or ad-hoc training.	"Sometimes, it's hard to access the internet… there are internet outages for a week" (P1) "Not all areas have internet… there are buildings with weak internet access" (P2) "We don't have it in the subject or syllabus… only in projects 1 and 2" (P3)
Lecturer Competency	Self-assessment of IoT skills	Senior lecturers admit low competency; newer lecturers seen as more adept. Rapid changes in IoT make it difficult to keep up.	"New lecturers are really competent to use IoT, but old lecturers are a little lacking" (P1) "I am not competent… this technology is developing too fast" (P2) "I am really not competent… if I want to do programming… I can't do it" (P3)
Coping Strategies	Self-learning and improvisation	Lecturers rely on self-directed learning, short courses, or workaround solutions when IoT access is limited.	"We have to develop ourselves" (P2) "We have to learn by ourselves... there is a course like Arduino... but it is not integrated in the subject" (P3)
Institutional Support	Frameworks and SOPs	General SOPs exist, but no IoT-specific competency model/framework is available in Polytechnics. Training opportunities are declining.	"There is an SOP, but there is no framework or model specifically for IoT" (P1) "So far it's only SOP but for IoT... there is no more" (P2) "It's more of a one-time thing... structured for this IoT, there is none" (P3)
Future Needs	Development of IoT competency model	All participants strongly support the need for a formal IoT competency model for lecturers to guide integration in teaching.	"It is necessary, because this matter is new. A lot of it is just general" (P1) "This study is necessary… in this automotive field still doesn't exist yet, no integration on new technology yet" (P2) "Once this lecturer is equipped with the skills… he can easily guide students" (P3)

Table 3 shown the findings from the interviews revealed a shared recognition among participants that IoT is increasingly important in both industry and education. All three lecturers acknowledged that IoT plays a crucial role in the automotive field, particularly in diagnostics, vehicle maintenance, and access to digital resources. However, they also pointed out that IoT has not been fully integrated into the Polytechnic curriculum, with its presence mostly limited to final year projects rather than formal teaching modules.

In terms of individual competency, participants consistently admitted that they did not consider themselves fully competent in applying IoT in teaching. While younger lecturers were perceived as more technologically adept, senior lecturers described themselves as struggling to keep pace with rapid technological changes. One participant noted, "New lecturers are really competent to use IoT, but old lecturers are a little lacking".

Challenges identified by the lecturers centred on infrastructure and training. Internet connectivity issues were frequently mentioned, with unstable access hindering classroom application. Limited financial allocation for reliable internet and lack of structured training programs were also seen as barriers. One lecturer explained that IoT-related courses they attended were "one-time programs" without long-term follow-up, reflecting a fragmented approach to professional development.

When asked about the existence of IoT competency frameworks or SOPs, all three participants stated that while general SOPs exist, no specific framework guides IoT integration at the Polytechnic level. This gap underscores the absence of a structured approach to competency development. Participants strongly agreed on the need for a competency model tailored to IoT in Mechanical and Automotive Engineering. One respondent summarized: "This study is necessary… in this automotive field still doesn't exist yet, no integration on new technology yet".

Overall, the analysis highlights six key issues: the recognized importance of IoT, lecturers' limited competency, challenges faced and how to cope it, systemic barriers to implementation, and the urgent need for a structured competency model. These findings provide a foundation for the development of a Polytechnic IoT competency framework, reflecting the type of preliminary insights emphasized in earlier exploratory studies (Mohd Ahyan et al., 2023).

Discussion

Table 4

Summary of Results

Towards an IoT Competency Model for Polytechnic Lecturers: A Preliminary Study **Objective:** To discover Polytechnic lecturers on perceiving the importance, competency, challenges, and the need for an IoT competency model in Mechanical Engineering (Automotive).		
Themes	**Sub-themes**	**Results**
Importance of IoT	Relevance in teaching and Industry	Lecturers agreed IoT is very important in automotive education and industry, especially for diagnostics, maintenance, and accessing global digital resources. However, IoT is not fully integrated into the current Polytechnic curriculum, appearing mainly in projects.
Challenges	Infrastructure and curriculum limitations	Major barriers include unstable internet connectivity, insufficient funding for facilities, lack of structured training, and the absence of IoT in formal syllabi. IoT exposure occurs mainly through ad hoc courses or student projects.
Competency	Self-perceived competency	Lecturers generally considered themselves not fully competent in applying IoT. Senior lecturers felt left behind compared to younger colleagues. Rapid technological changes make it difficult to maintain competence.
Coping Strategies	Self-learning and improvisation	Lecturers rely on self-directed learning, occasional workshops, and improvised solutions. They stressed that current efforts are fragmented and not systematically supported by the institution.
Institutional Support	Frameworks and SOPs	While general SOPs exist, no IoT-specific competency framework or structured professional development model is available at Polytechnics. Training opportunities have declined due to budget constraints.
Future Needs	Development of IoT competency model	All lecturers strongly supported the need for a formal IoT competency model to guide lecturers' skill development and teaching practice in Mechanical and Automotive Engineering.

As shown in Table 4, the findings of this preliminary study highlight a growing recognition among Polytechnic lecturers that the Internet of Things (IoT) is increasingly important in Mechanical Engineering (Automotive). All three participants acknowledged the relevance of IoT for vehicle diagnostics, maintenance, and access to global digital resources. This aligns with research that situates IoT as a central enabler in the automotive sector, where connected systems, predictive maintenance, and intelligent transport have become integral to industry practice (AlHousrya et al., 2025; Rahim et al., 2021). Yet, despite this recognition, IoT remains marginal within the Polytechnic curriculum, appearing mostly in final year projects rather than embedded across courses. This gap reflects what earlier scholars have described as a lag between industrial innovation and educational adaptation, particularly in vocational contexts (Azmi, 2022).

One of the most striking findings concerns the lecturers' limited sense of competence in IoT. Participants consistently described themselves as not fully equipped to teach IoT concepts, with senior lecturers in particular noting difficulties in keeping pace with rapid technological advances. Similar patterns have been observed in other studies, where educators' readiness is uneven and often dependent on exposure to training opportunities (Junus et al., 2021; Munyaradzi et al., 2024). The rapid pace of technological change in automotive systems, where yesterday's diagnostic methods are quickly outdated by new IoT-based tools that was identified as a key source of this competency gap. This suggests that continuous professional development, rather than one-off training sessions, is required if lecturers are to remain relevant in an evolving field.

Institutional barriers further compound these challenges. Participants pointed to unstable internet connectivity, inadequate funding for facilities, and declining training opportunities as obstacles to effective IoT adoption. These findings echo broader concerns in the literature that highlight how infrastructural limitations and resource shortages undermine the integration of new technologies into education (Rahman, 2024). Without stable digital infrastructure and systematic capacity-building initiatives, lecturers are left to rely on self-directed learning and ad hoc solutions, which often leads to fragmented and inconsistent outcomes.

Another critical issue is the absence of a formal IoT competency model for Polytechnic lecturers. While general SOPs exist, none of the participants could identify a framework that specifically guides IoT teaching or professional expectations in the automotive domain. This gap resonates with competency model research, which emphasizes the importance of explicit frameworks in aligning training with workplace demands (Arribas-Aguila et al., 2024). Effective competency models have been shown to bridge the divide between theory and practice by offering structured pathways for skill development (Kart & Şimşek, 2024). In the context of IoT, such a model would need to cover technical domains (e.g., sensors, embedded systems, networking, data analytics), pedagogical strategies for classroom integration, and transversal skills such as adaptability and problem-solving.

Finally, the strong consensus among participants that a competency model is urgently needed provides important implications for future policy and curriculum development. This mirrors international calls for education systems to develop frameworks that prepare lecturers and students for Industry 4.0 and beyond (Nováková et al., 2024). By equipping lecturers with a structured IoT competency framework, Polytechnics can better align their programs with industry standards, ensure graduates are work-ready, and reduce the gap between educational offerings and labor market needs.

Taken together, these findings reinforce the argument that lecturers' readiness for IoT cannot be reduced to individual skill levels alone. Rather, it is shaped by systemic infrastructure, institutional support, and the availability of structured competency models. This study contributes early evidence that can guide the development of such a framework, serving as a foundation for larger-scale research to validate and refine an IoT competency model tailored to the needs of Malaysian Polytechnics. Table 4 shown the summary of results for the discussion of this study.

Conclusion

This preliminary study explored Polytechnic lecturers' perceptions of IoT in Mechanical Engineering (Automotive). The findings revealed a shared recognition of IoT's importance in modern automotive practices, yet lecturers admitted limited competency and highlighted systemic challenges such as unstable internet access, lack of structured training, and absence of an IoT-focused framework. While IoT has begun to surface in projects and workshops, it remains marginal in the curriculum, leaving lecturers to rely on fragmented, self-directed learning. These insights underscore a significant competency gap that, if unaddressed, risks widening the divide between educational practice and industrial demands in the era of Industry 4.0.

To address these challenges, the study recommends the development of a structured IoT competency model for Polytechnic lecturers. Such a framework should encompass technical skills, pedagogical strategies, and transversal competencies, while being supported by systematic training and institutional resources. Policymakers, curriculum developers, and institutional leaders are urged to prioritize IoT integration within Polytechnic programs, ensuring lecturers are empowered to guide students effectively. Strengthening lecturer readiness through targeted frameworks and continuous professional development will be essential for aligning Malaysia's TVET education with the evolving needs of the automotive industry.

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