A Conceptual Framework for Inquiry Integrated Technological Literacy in Malaysian Vocational Education

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Abstract
Rapid advancements in artificial intelligence, automation, and data-driven technologies have elevated technological literacy as a core competency for Industry 4.0. In Malaysian vocational education, the Final Year Project (FYP) is expected to serve as a platform for demonstrating technological capability. However, current practices remain largely product-oriented and provide limited opportunities for learners to develop the conceptual reasoning, analytical judgement, and reflective understanding required in technologically intensive environments. This conceptual paper synthesises literature on technological literacy, inquiry-based learning, and vocational project pedagogy to address this misalignment. Guided by constructivist theory and the Technology Acceptance Model, the paper proposes an integrated inquiry-centred framework comprising orientation, conceptualisation, investigation, synthesis, and reflection as iterative phases that strengthen technological literacy. Evidence from institutional guidelines shows that inquiry processes such as problem framing, technological evaluation, and reflective reasoning are underrepresented in existing FYP structures. The proposed framework offers theoretical and pedagogical direction for teachers, curriculum designers, and policymakers seeking to redesign vocational learning environments in line with Industry 4.0 expectations. The study contributes a structured and research-informed model for embedding inquiry into the FYP to enhance technological literacy and workforce readiness in Malaysia's TVET system.
Keywords: Technological Literacy, Inquiry Based Learning, Vocational Education, Industry 4.0 Competencies, Final Year Project Framework

Introduction

Rapid advancements in artificial intelligence, automation, and data-driven technologies have reshaped industrial systems and intensified the need for workers who can interpret digital processes, analyse system behaviour, and make evidence-based technological decisions. Industry 4.0 therefore positions technological literacy as a cognitive capability that extends beyond operational usage to include conceptual understanding, analytical reasoning, and reflective judgement (Lee, 2025). As Malaysia accelerates its national digitalisation agenda, vocational education plays a critical role in preparing learners who can navigate these technologically complex environments. Strengthening technological literacy has become a central expectation of vocational training in this context.

Within this evolving landscape, the Final Year Project (FYP) is widely regarded as a major learning platform for demonstrating technological capability in vocational institutions. Traditionally, the FYP has functioned as a task that emphasises technical completion and product output. However, recent scholarship highlights a shift toward inquiry-driven project work that values conceptual exploration, investigation, and reflective evaluation. Tafahomi and Chance (2024) show that disciplines such as architecture and engineering are reframing the FYP as a research-informed process requiring analytical and interpretive engagement. This shift suggests that vocational FYPs in Malaysia must also evolve to support deeper forms of technological understanding. Literature consistently emphasises that technological literacy develops when learners actively interrogate technological problems, justify decisions, and construct meaning through inquiry.

Despite these international developments, Malaysian vocational FYP structures continue to prioritise procedures and technical artefacts while underrepresenting processes such as problem framing, technological justification, and reflective reasoning. Husin et al. (2024) report that existing guidelines often reward product completion more than conceptual engagement, which restricts learners' opportunities to develop higher-order technological thinking. Studies also indicate that an excessive emphasis on routine tasks constrains learners' capacity to interpret system behaviour, diagnose problems, and adapt to technological uncertainty, all of which are essential competencies for effective participation in Industry 4.0. This pedagogical misalignment signals the need for a reorientation toward inquiry-based approaches.

Inquiry-based learning offers a structured pathway for nurturing the cognitive, analytical, and reflective habits required in technologically intensive environments. Pharamela and Singh Pillay (2025) demonstrate that inquiry strengthens digital resilience and enhances the ability to reason through technological processes. Research further suggests that inquiry mirrors workplace expectations in which workers must analyse data, manage uncertainty, and justify technological decisions. Integrating inquiry into the FYP therefore has the potential to transform technological learning and align it more closely with contemporary industrial demands.

The theoretical foundations of constructivist learning and the Technology Acceptance Model (TAM) provide a basis for reconceptualising the FYP as an inquiry-driven process. Constructivism explains how learners build understanding through active engagement, interpretation, and reflection, while TAM highlights how perceptions of usefulness and ease

of use shape interactions with digital tools (Shehadeh, 2025). Together, these perspectives emphasise the cognitive and motivational conditions that support technological literacy.

Although the FYP is intended to serve as a major platform for developing technological capability in Malaysian vocational education, current practices remain heavily product-oriented and offer limited opportunities for learners to develop the conceptual, analytical, and reflective skills required for Industry 4.0. This gap underscores the need for an integrated inquiry-based framework that can guide educators, curriculum designers, and policymakers in strengthening technological literacy through the FYP.

Technological Literacy in the Context of Industry 4.0

Technological literacy has become a central capability in modern industries that rely on interconnected, data driven, and automation-based systems. Industry 4.0 environments require individuals to interpret digital information, understand system behaviour, and make decisions supported by analytical reasoning. These expectations extend technological literacy beyond technical operation to include conceptual understanding, reflective judgement, and problem solving (Yunos & Madar, 2025). Vocational learners therefore need structured learning opportunities that strengthen these cognitive capacities.

Digital transformation has increased the complexity of workplace tasks. Garcés et al. (2025) note that workers must understand how data moves through technological systems, how automated responses are generated, and how digital tools interact within organisational contexts. Rosli and Matore (2023) observe that vocational learners often struggle with these conceptual demands because their training emphasises procedural tasks rather than analytical engagement. When learners focus primarily on routine procedures, they may not acquire the ability to diagnose technological problems or adapt to new conditions, which limits their readiness for contemporary workplaces.

Research shows that technological literacy is strengthened when learners engage with complexity and uncertainty. Lourenço et al. (2025) explain that inquiry-oriented environments encourage learners to examine unfamiliar technological problems and interpret emerging digital behaviours. Huang et al. (2024) add that inquiry connects theoretical concepts with technological actions because learners must evaluate evidence and justify their reasoning. Such engagement promotes deeper and more transferable technological understanding.

Scholarly work on digital transformation highlights the broader relevance of technological literacy. Felipe et al. (2025) explain that digital transformation operates across several interconnected layers, including the individual layer, the organisational layer, and the wider system layer. Workers must interpret technological problems within each of these contexts, which demonstrates the need for flexible and analytical forms of technological understanding.

Sector specific literature illustrates increasing technological demands. Parra-López et al. (2025) show that industries such as agriculture and food processing depend on artificial intelligence, robotics, blockchain, and remote sensing technologies. These tools require workers to interpret digital outputs, evaluate technological implications, and justify

operational decisions. Mhaske et al. (2025) report ongoing gaps in analytical reasoning and technological adaptability and attribute these gaps to limited opportunities for exploration and reflective engagement in many training environments. Pedagogical models that support investigation and evidence-based decision making are needed to address these gaps.

Human and psychological dimensions also influence technological literacy. Farmanesh et al. (2025) explain that rapid technological change can create technostress when individuals feel unprepared for digital demands. Inquiry based learning helps reduce these pressures by strengthening technological self-efficacy through exploration and reflection. Anshari and Ordóñez de Pablos (2025) emphasise the importance of combining technological understanding with sustainability-oriented reasoning. Muzulon et al. (2025) note that technological literacy develops progressively across career stages, making early exposure important for future growth. Safa'atillah et al. (2025) further demonstrate that technological literacy has become an essential competency across organisations.

Overall, the literature portrays technological literacy as a dynamic construct shaped by conceptual, analytical, behavioural, and psychological components. Industry 4.0 environments require vocational learners to evaluate, interpret, and justify technological actions rather than rely on procedural knowledge. Inquiry based learning offers a pathway for developing these capabilities because it encourages exploration, evidence based reasoning, and reflective judgement within technological contexts.

Inquiry Pedagogy and Digital Competence in Vocational Education

Inquiry based learning has become an important pedagogical approach for strengthening the cognitive and analytical abilities required in technologically advanced environments. Through inquiry, learners examine technological issues, interpret information, and construct meaning through guided investigation. Huang et al. (2024) explain that inquiry promotes deeper technological understanding because learners evaluate concepts actively and consider the implications of their decisions. This process supports the development of technological competence in ways that routine procedural instruction cannot achieve.

Digital competence within vocational education extends beyond operational skills to include the ability to understand technological systems, analyse digital information, and make informed decisions. Pasi and Dhamak (2024) argue that inquiry aligns naturally with these expectations because learners are encouraged to question processes, examine system behaviour, and compare potential solutions. Such engagement supports the development of flexible thinking and a more integrated understanding of how digital systems function in practice.

Inquiry based learning also contributes to technological autonomy and digital confidence. Qiong et al. (2024) show that cycles of exploration, experimentation, and reflection help learners build self-efficacy when working with unfamiliar technological tools. These experiences develop adaptive behaviour, which is essential in vocational contexts that require learners to respond to evolving digital demands. Inquiry positions technology as a subject of investigation, enabling learners to develop reflective habits that support long term professional growth.

Collaboration and communication, which form important components of digital competence, are also strengthened through inquiry processes. Hinostroza et al. (2024) note that inquiry fosters shared reasoning because learners must articulate interpretations, justify technological choices, and consider alternative viewpoints. These collaborative practices reflect workplace expectations in which technological problems are addressed collectively and require clear communication. Research shows that inquiry supports the development of communication skills by encouraging learners to explain technological reasoning in structured and coherent ways.

Overall, existing literature demonstrates that inquiry pedagogy promotes conceptual understanding, analytical reasoning, reflective judgement, adaptive behaviour, and collaborative engagement. These capabilities are essential for vocational learners who must participate effectively in Industry 4.0 environments and respond confidently to emerging technological challenges.

The Final Year Project as a Catalyst for Technological Literacy

The Final Year Project (FYP) plays an important role in vocational education because it brings together theoretical learning, practical application, and technological engagement within an authentic task. It provides learners with a structured space to analyse problems, justify technological decisions, and demonstrate their understanding of digital processes. Husin et al. (2024) highlight that the FYP has the potential to cultivate deep technological literacy when it encourages inquiry, conceptual reasoning, and reflective thinking rather than focusing only on procedural completion. When learners are required to articulate their decisions and evaluate technological outcomes, they develop a stronger foundation for engaging with advanced digital systems.

Although the FYP has traditionally been viewed as a demonstration of technical proficiency, recent scholarship shows that its function is gradually shifting toward a more inquiry centred form of learning. Tafahomi and Chance (2024) report that disciplines such as architecture and engineering now frame the FYP as an investigative process that includes problem identification, analysis, synthesis, and reflective evaluation. This shift reflects broader expectations within Industry 4.0, where workers must reason through technological issues, compare alternative approaches, and justify decisions based on analytical insight. When positioned in this way, the FYP becomes a platform that supports the development of technological literacy by enabling learners to construct understanding rather than simply complete a set of technical steps.

Existing evidence suggests, however, that many vocational FYPs continue to emphasise product outcomes at the expense of conceptual engagement. Tshong and Yasin (2023) explain that learners are often assessed on the technical quality of their final product, while processes such as problem framing, investigation, and reflective analysis receive less attention. This emphasis can restrict opportunities for learners to understand how technological systems function, evaluate the implications of their choices, or analyse the behaviour of digital tools. Such limitations reduce the potential of the FYP to support the learning required for participation in complex Industry 4.0 environments.

Inquiry driven FYPs can create learning conditions that mirror workplace expectations. Jalil et al. (2024) show that when learners examine technological assumptions, test ideas, and evaluate the outcomes of their decisions, they develop stronger analytical and reflective abilities. These forms of engagement resemble real industrial settings, where individuals must interpret data, make decisions based on evidence, and respond to uncertainty. Inquiry based FYPs therefore provide meaningful experiences that help learners adapt to technological challenges and develop confidence when interacting with digital tools.

The literature collectively indicates that the FYP can become a powerful catalyst for developing technological literacy when it adopts inquiry principles that emphasise analysis, reasoning, and reflection. This approach transforms the FYP from a product focused task into an opportunity for learners to deepen their conceptual understanding and technological decision making. Such a shift supports the development of graduates who can engage with the complex systems and analytical demands found in Industry 4.0 environments.

Constructivism and the Technology Acceptance Model as Pedagogical Anchors
Constructivism provides an important theoretical perspective for understanding how learners acquire technological literacy through active engagement with meaningful learning tasks. It assumes that knowledge is built through processes of exploration, interpretation, and reflection rather than through the passive reception of information. Jalil et al. (2024) note that constructivist environments encourage learners to work with technological tools, test their ideas, and relate new information to their existing understanding. These activities help learners form deeper conceptual connections and develop the cognitive structures necessary for interpreting technological systems. Constructivism therefore supports the development of technological literacy by promoting active reasoning and reflective engagement.

Reflection represents a central component of constructivist learning and plays an important role in technological development. Güner and Erbay (2021) explain that reflective processes allow learners to evaluate their decisions, consider the effectiveness of their technological actions, and refine their understanding of how technologies function. Through reflection, learners gain awareness of their reasoning processes and develop the capacity to justify their decisions based on evidence. This form of reflective judgement is critical in Industry 4.0 environments, where individuals must continually assess their technological choices and adapt to evolving digital conditions.

The Technology Acceptance Model (TAM) complements constructivism by addressing the psychological and motivational factors that influence learners' engagement with digital tools. TAM proposes that perceived usefulness and perceived ease of use shape an individual's intention to adopt technology. Shehadeh (2025) observes that learners are more likely to use digital tools meaningfully when they believe that technology supports their inquiry, problem solving, and performance needs. Inquiry based learning environments strengthen these perceptions by placing technology within authentic investigative tasks, where learners can observe its relevance and utility. This alignment supports purposeful technological engagement and increases learners' willingness to explore and analyse digital tools.

When considered together, constructivism and TAM provide a coherent pedagogical foundation for structuring technological learning experiences. Constructivism explains how learners construct understanding through inquiry, interpretation, and reflection, while TAM highlights the motivational conditions that support sustained interaction with digital tools. Vong et al. (2025) argue that learning environments that integrate cognitive and motivational dimensions better prepare individuals for technologically intensive workplaces. These perspectives reinforce the importance of designing learning conditions that encourage exploration, analytical reasoning, and reflective evaluation, all of which support the development of technological literacy.

The combined insights from constructivism and TAM suggest that effective technological learning environments must engage learners both cognitively and motivationally. Inquiry based approaches supported by these theories encourage learners to make sense of technological problems, evaluate evidence, and develop the confidence needed to interact with advanced digital systems. These theoretical foundations provide a strong basis for designing learning practices that strengthen technological literacy in vocational education.

Integrated Inquiry Technological Literacy Framework
The integrated inquiry technological literacy framework conceptualises technological learning as a cyclical and iterative process that supports the development of analytical, cognitive, and reflective abilities required in Industry 4.0 environments. This framework is organised into five interconnected phases, namely inquiry orientation, inquiry conceptualisation, inquiry investigation, inquiry synthesis, and inquiry reflection. These phases represent a sequence of learning experiences that encourage exploration, interpretation, and evidence-based reasoning. Poupard et al. (2025) explain that learning structures organised around curiosity and cognitive engagement support the development of deep understanding, which aligns with the goals of technological literacy.

Inquiry orientation represents the starting point of the framework by stimulating learners' curiosity and preparing them to engage with technological contexts. During this phase, learners explore authentic situations that highlight the relevance of technology in real problems. Poupard et al. (2025) emphasise that curiosity driven activities enhance conceptual receptiveness and motivate learners to participate more actively in subsequent inquiry processes. Within vocational settings, this phase allows learners to situate their Final Year Projects within broader technological landscapes and recognise the importance of the issues they are addressing.

Inquiry conceptualisation requires learners to define technological problems, formulate questions, and identify initial assumptions. Eyadat (2023) notes that problem framing is often overlooked in vocational learning even though it forms a crucial element of technological reasoning. Effective conceptualisation enables learners to determine the conceptual variables that influence technological decisions and to clarify the direction of their investigation. This phase strengthens learners' ability to articulate technological challenges clearly and to organise their reasoning around coherent investigative goals.

Inquiry investigation forms the analytical core of the framework. During this phase, learners gather information, test ideas, and interpret technological behaviours. Lourenço et al. (2025) highlight that investigative inquiry encourages learners to confront uncertainty, analyse evidence, and refine their understanding through iterative engagement. These activities resemble authentic workplace situations in which workers must diagnose technological issues, compare alternatives, and respond to emerging conditions. Inquiry investigation therefore supports the development of technological resilience and analytical flexibility.

Inquiry synthesis requires learners to integrate their findings, evaluate alternatives, and construct coherent technological solutions. Xiaoxuan and Pamintuan (2025) explain that synthesis involves reconciling information, assessing the effectiveness of technological options, and developing interpretations that are supported by evidence. This phase helps learners organise their investigative experiences into structured understanding and strengthens their ability to reason about technological systems in comprehensive and coherent ways.

Inquiry reflection concludes the learning cycle by prompting learners to evaluate their decisions, consider the implications of their actions, and examine how their understanding has evolved. Güner and Erbay (2021) highlight those reflective processes promote metacognitive development by helping learners identify strengths, recognise limitations, and plan for improvement. In technological contexts, reflection enables learners to internalise concepts and enhance their capacity for self-regulated learning. The reflective outcomes of this phase naturally stimulate renewed curiosity, which leads learners back into further inquiry.

Taken together, these five phases provide a structured pathway for embedding inquiry within technological learning. The framework supports the development of technological literacy by enabling learners to explore technological problems, interpret evidence, synthesise understanding, and reflect on their reasoning. These capabilities align with the cognitive, analytical, and reflective demands of Industry 4.0 environments and provide vocational learners with the foundation needed for confident engagement with advanced digital systems.

Implications for Teachers, Curriculum and Policy
The integration of an inquiry based technological literacy framework has several implications for teachers because instructional practices determine the extent to which inquiry becomes a central element of vocational learning. Teachers play a key role in creating environments that encourage questioning, analysis, and reflective engagement. Lee (2025) notes that teachers must adopt facilitative approaches that guide learners in interpreting technological information, evaluating evidence, and constructing understanding through inquiry. Such pedagogical shifts require professional development that equips teachers with strategies for modelling inquiry behaviours, designing investigative tasks, and supporting reflective thinking. When teachers create learning spaces that value reasoning and exploration, learners develop stronger technological literacy that aligns with Industry 4.0 expectations.

Curriculum designers also hold important responsibilities because curriculum structures shape how inquiry is incorporated into vocational learning. Jalil et al. (2024) argue that curriculum frameworks must explicitly include processes such as orientation, conceptualisation, investigation, synthesis, and reflection to support the systematic development of technological literacy. This requires reviewing existing project guidelines and assessment practices to ensure that analytical and reflective components receive appropriate emphasis. Assessment rubrics should evaluate learners' ability to interpret technological problems, use evidence to justify decisions, and reflect on their learning processes. When curriculum structures recognise inquiry as a core expectation, learners experience greater coherence between instructional goals and assessment standards.

Policy implications arise from national efforts to strengthen digital readiness and technological capability across the vocational education sector. Vong et al. (2025) explain that national strategies that promote inquiry-based and technology enabled learning contribute to workforce preparedness by developing analytical and adaptive competencies. Policymakers can support the adoption of inquiry centred approaches by providing adequate resources, updating institutional guidelines, and encouraging collaboration between vocational institutions and industry partners. Such measures enhance institutional capacity to implement learning environments that reflect the cognitive and technological demands of Industry 4.0. Policy alignment ensures that vocational education remains responsive to national goals for technological advancement and economic competitiveness.

Industry stakeholders also benefit from learning environments that emphasise inquiry. Pharamela and Singh Pillay (2025) report that modern workplaces require individuals who can analyse technological situations, justify decisions, and respond to changing digital demands. When vocational institutions embed inquiry into the Final Year Project and related learning tasks, they produce graduates who demonstrate these qualities and are better prepared for professional settings. Strong partnerships between vocational institutions and industry can further ensure that inquiry-based learning remains relevant to real technological challenges and aligns with expectations for workforce readiness.

Overall, these implications highlight the need for coordinated efforts across instructional, curricular, and policy levels to strengthen technological literacy within vocational education. Teachers must facilitate inquiry, curriculum designers must embed it structurally, and policymakers must support its implementation through strategic alignment with national goals. When these elements operate collectively, vocational institutions are better positioned to develop learners who can engage confidently with the demands of Industry 4.0 technologies.

Conclusion

Technological literacy has emerged as a critical capability for vocational learners who must operate within environments shaped by rapid digital transformation. Many vocational learning practices still focus heavily on technical completion, which restricts opportunities for learners to develop the conceptual thinking, analytical judgement, and reflective understanding required in technologically intensive settings. This limitation demonstrates the need for approaches that move beyond procedural tasks and emphasise deeper engagement with technological problems.

Inquiry based learning provides a meaningful method for strengthening technological literacy because it encourages learners to explore ideas, interpret information, evaluate alternatives, and reflect on their understanding. When learners investigate technological issues through structured inquiry, they develop the cognitive flexibility and reasoning abilities needed to respond confidently to complex digital conditions. Constructivist perspectives and motivational factors further support the development of these capabilities by highlighting the importance of active engagement, purposeful exploration, and reflective evaluation.

The integrated inquiry technological literacy framework presented in this paper offers a structured pathway for enhancing technological learning in vocational education. The five phases of the framework, namely orientation, conceptualisation, investigation, synthesis, and reflection, collectively guide learners through experiences that promote critical thinking, evidence informed decision making, and deeper understanding of technological systems. These phases support sustained engagement with technological problems and strengthen learners' ability to justify, interpret, and evaluate their technological actions.

The framework also carries practical implications for teachers, curriculum designers, policymakers, and industry partners. Teachers play an important role in facilitating inquiry-based learning. Curriculum designers must embed inquiry processes within project guidelines and assessment structures so that analytical and reflective components are valued. Policymakers can support inquiry-based approaches by aligning institutional expectations with national digital transformation priorities. Industry stakeholders benefit from graduates who demonstrate technological reasoning, adaptability, and confidence in managing technological challenges.

Overall, this conceptual paper provides a foundation for rethinking technological learning in vocational education through a structured inquiry-based approach. As vocational institutions respond to the increasing complexity of digital environments, the adoption of inquiry centred practices can help produce graduates who are capable of reflective reasoning, analytical thinking, and informed technological decision making. These qualities are essential for meaningful participation in the evolving landscape of Industry 4.0.

Theoretical and Contextual Contributions

This study offers both theoretical and contextual contributions to the field of vocational education and technological literacy. Theoretically, it advances existing scholarship by synthesising constructivist learning theory and the Technology Acceptance Model into an integrated inquiry centred framework that reconceptualises technological literacy as a process oriented, cognitive, and reflective capability rather than a purely operational or technical skill. By structuring technological learning through iterative inquiry phases that include orientation, conceptualisation, investigation, synthesis, and reflection, this study extends current discussions on inquiry-based learning by explicitly positioning inquiry as a mechanism for developing higher order technological reasoning within vocational Final Year Projects. In doing so, the proposed framework contributes to theory by clarifying how inquiry processes support the formation of analytical judgement, conceptual understanding, and reflective decision making in technologically intensive learning environments.

Contextually, this study contributes to the Malaysian Technical and Vocational Education and Training literature by addressing a documented gap between Industry 4.0 competency expectations and prevailing product focused Final Year Project practices. The proposed framework offers a locally grounded and research informed model that aligns vocational project pedagogy with national digital transformation and workforce readiness goals. By providing practical direction for educators, curriculum designers, and policymakers, the framework supports ongoing efforts to strengthen technological literacy and to better prepare vocational graduates for meaningful participation in Malaysia's evolving Industry 4.0 ecosystem.

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