INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT
OPEN ACCESS JOURNAL
Vol 14, Issue 4, (2025) E-ISSN: 2226-6348

Relationships among AI Competency, AI Anxiety, and Inquiry-Based Teaching among Science Teachers

Siti Nur Diyana Mahmud, Noor Amira Ramli
Faculty of Education, Universiti Kebangsaan Malaysia
*Corresponding Author Email: diyana@ukm.edu.my

DOI Link: http://dx.doi.org/10.6007/IJARPED/v14-i4/26701

Published Online: 21 October 2025

Abstract
As Artificial Intelligence (AI) becomes increasingly integrated into science education, questions of teacher preparedness and emotional response come to the fore. This quantitative study explored three key dimensions: (a) the levels of AI competency and anxiety among secondary science teachers, (b) differences in these levels based on school location and teaching experience, and (c) how these factors relate to the use of structured, guided, and open inquiry-based teaching practices. A total of 136 teachers from a Malaysian state participated in the study by completing validated Likert-scale surveys. Results showed that teachers generally reported moderate levels of AI competency (M = 3.65, SD = 0.69) and AI-related anxiety (M = 3.24, SD = 0.64). Among the inquiry approaches, guided inquiry was most used, followed by structured and open formats. A multivariate analysis of variance (MANOVA) revealed that teaching experience had a significant influence on combined competency and anxiety levels, with teachers in the 6–10 years' experience range reporting the highest competency. School location did not impact competency but did have a small, statistically significant effect on anxiety, with higher levels reported among rural teachers. Correlation analyses further indicated small but positive relationships between AI competency and all three inquiry styles, whereas anxiety showed no significant association with inquiry use. These findings point to AI competency rather than anxiety as the key driver of inquiry-based teaching involving AI. The study highlights the need for targeted professional development that builds classroom-ready AI skills, enhances assessment literacy, and addresses contextual challenges in rural settings.
Keywords: Ai in Education, Teacher Competency, Anxiety, Inquiry-Based Science Teaching, Malaysia

Introduction

Artificial Intelligence (AI) has quickly shifted from being a futuristic concept to becoming a practical tool embedded in the everyday functioning of schools. Within science education, AI technologies now support a range of instructional tasks including data analysis, simulations, personalized feedback, adaptive learning pathways, content creation, and large-scale learning analytics. These capabilities align closely with the aims of inquiry-based science education

(IBSE), where students are expected to formulate questions, conduct investigations, interpret data, and build evidence-based explanations. When thoughtfully integrated, AI has the potential to reduce the logistical burdens that often hinder inquiry-based instruction, for example, by automating data cleaning, highlighting trends or anomalies, and providing metacognitive prompts that encourage deeper reflection. These affordances can free teachers to focus more on guiding students' reasoning, supporting scientific argumentation, and fostering meaningful classroom dialogue.

However, the presence of advanced tools does not automatically lead to improved teaching or learning. The successful adoption of AI in classrooms depends heavily on teacher-level factors, most notably their pedagogical–technological competency and their comfort or anxiety regarding AI. Competency in this context encompasses a teacher's understanding of AI tools and concepts, the ability to select and align these tools with instructional goals, and the skill to manage AI-supported learning activities including planning, orchestration, and assessment. Crucially, it also involves designing fair and transparent ways to evaluate student learning in AI-mediated environments. Anxiety, meanwhile, reflects teachers' concerns about shifting professional roles, increased workloads, ethical and equity issues, and the potential effects of AI on student cognition and academic integrity. Importantly, competency and anxiety are not mutually exclusive; a teacher may feel capable of using AI and still harbour significant concerns about its broader implications.

Understanding how these two dimensions, competency and anxiety interact, and how they influence classroom practice, is vital for informing policy, professional development, and implementation strategies. This is particularly true in Malaysia, where recent educational reforms have emphasized digital transformation, STEM education, and inquiry-oriented teaching as key drivers of national progress. Policies such as the Digital Education Strategy signal a strong push toward technology integration aimed at cultivating higher-order thinking skills and reducing educational disparities. Yet, as with any reform effort, implementation is shaped by local realities—such as uneven access to devices, bandwidth constraints, and the demands of high-stakes testing. These conditions affect not only what teachers can do but also how they feel about doing it. In well-resourced environments, teachers may feel empowered to experiment; in resource-constrained settings, even confident teachers may hesitate due to the high perceived risks of failure.

Despite rapid diffusion of AI, the bottleneck in AI-supported IBSE is teacher competency, not merely attitudes. Without classroom-ready competencies, particularly in assessment literacy (making student reasoning visible, distinguishing student work from tool output, and assuring integrity), AI risks becoming a shortcut rather than a cognitive partner. This matters now because Malaysian education policy emphasises digital transformation and inquiry-oriented teaching to strengthen higher-order thinking and reduce disparities. Yet implementation remains uneven, especially where connectivity and device access are fragile.

This study is grounded in three theoretical traditions. First, the technological–pedagogical knowledge (TPACK) framework emphasizes the integration of content, pedagogy, and technology as a foundation for effective teaching. Second, social-cognitive theory highlights the role of mastery experiences in developing self-efficacy, the belief that one can successfully manage challenging tasks. Finally, implementation frameworks remind us that having the technical skill is not always enough; successful integration also depends on attitudes, values, and the broader teaching context.

Adding another layer of complexity is the nature of inquiry-based instruction itself. While open inquiry is where students formulate their own questions and investigations, is often viewed as the ideal, many classrooms operate within more structured or guided formats due to curricular and logistical constraints. Each of these modes' places different demands on the teacher in terms of planning, classroom management, and assessment. Although AI could help shift practice along this continuum, its successful application depends on teachers being able to design tasks that leverage AI as a cognitive partner not a shortcut and to assess student learning in ways that honour both process and product.

In light of these dynamics, this study addresses three pressing questions: (1) What are the current levels of AI-related competency and anxiety among secondary science teachers? (2) Do these levels vary based on school location or teaching experience? and (3) How are competency and anxiety related to teachers' use of structured, guided, and open inquiry practices? By investigating these questions in a Malaysian context, this study aims to provide timely, evidence-based guidance for professional learning, instructional design, and education policy as AI continues to shape the future of science teaching.

Problem Statement

Although Artificial Intelligence (AI) offers clear benefits for inquiry-based science education (IBSE), the gap between potential and actual classroom practice remains wide. Many teachers express moderate familiarity with AI tools and acknowledge their value in enhancing instruction. Yet, translating this awareness into meaningful teaching practices continues to be a challenge. This disconnects stems from several practical barriers that hinder effective implementation.

First, teachers often find it difficult to identify and apply the most appropriate AI tool for a given instructional goal. Effective inquiry teaching requires alignment between the tool used, the learning objective, and the specific stage of student reasoning. Without this alignment, AI can risk becoming a shortcut that producing faster answers but bypassing the deeper thinking that inquiry-based learning is meant to cultivate.

Second, the successful integration of AI depends on a teacher's ability to guide students in using these tools productively. If orchestration is lacking, AI may either dominate the learning process or offer too little structure, leaving students confused or disengaged. Striking the right balance between support and autonomy remains a complex task.

The third, and perhaps most critical challenge lies in assessment. Teachers frequently struggle with how to fairly and effectively evaluate student learning in AI-enhanced environments. This includes distinguishing students' genuine reasoning from AI-generated outputs, making their thinking processes visible, and upholding academic integrity in a context where AI assistance is increasingly available.

Layered on top of these instructional challenges is the emotional dimension of AI integration namely, teacher anxiety. These concerns are not rooted in technophobia, but in legitimate apprehensions about shifting professional roles, increased workload, unreliable infrastructure, and ethical implications. In rural areas especially, where digital infrastructure is often less stable, the risks associated with using AI during instruction are heightened, intensifying teachers' anxiety even when they feel technically competent.

Furthermore, professional development (PD) efforts often fall short by focusing on "mindset" rather than material realities. Without addressing underlying conditions such as connectivity, device access, and assessment tools, PD risks adding pressure without offering actionable support. Similarly, innovation campaigns that emphasize enthusiasm over pedagogy can leave educators with unresolved questions about fairness, effectiveness, and practical application.

This study responds to three pressing gaps in the current evidence base:

1. What are the actual levels and patterns of AI-related competency and anxiety among secondary science teachers?
2. Do these patterns vary according to school location or years of teaching experience?
3. How do competency and anxiety relate to teachers' use of structured, guided, and open forms of inquiry instruction?

Clarifying these questions is essential for designing targeted professional development, allocating resources effectively, and building leadership capacity where it matters most. Without such clarity, attempts to scale AI-supported inquiry risk being misaligned with the realities of teachers' practice.

This study contributes (i) baseline metrics of AI competency and anxiety in Malaysian secondary science teaching, (ii) equity-relevant comparisons (urban–rural; career stages), and (iii) instructional linkages showing that competency—not anxiety is associated with greater use of structured, guided, and open inquiry. The findings inform professional development design (prioritising assessment literacy and task design), leadership strategy (leveraging mid-career teachers as peer mentors), and policy targeting (infrastructure and support in rural contexts).

Method

Research Design

This study adopted a quantitative, cross-sectional survey design to capture teachers' self-reported levels of AI competency, AI-related anxiety, and their use of various inquiry-based instructional practices. The design was selected for its capacity to explore relationships among multiple variables and to compare patterns across subgroups. Specifically, it allowed the researchers to assess how these constructs varied by school location (urban vs. rural) and teaching experience, while also examining the associations between teacher-level factors and the frequency of structured, guided, and open inquiry in science classrooms.

The analytic plan included descriptive statistics to establish baseline trends, multivariate and univariate analyses to test for group differences, and correlation techniques to explore potential relationships between variables. An alpha level of .05 was used to determine statistical significance throughout the study.

Context and Participants

The research was conducted in secondary schools located in Negeri Sembilan, a state in Malaysia. A total of 136 science teachers participated, representing a mix of disciplines including general science, physics, chemistry, and biology. Participants were recruited through school and district communication channels, with the goal of reaching educators who were currently teaching science subjects.

The sampling approach was pragmatic but intentional in seeking variation across both geographic location and levels of teaching experience. Teachers were grouped into four experience bands: less than 5 years, 6–10 years, 11–15 years, and 16 years or more. This allowed for meaningful comparisons across different career stages. Focusing exclusively on practicing science teachers ensured that responses reflected current classroom conditions, rather than abstract beliefs about AI or pedagogy.

Instrumentation

Data were collected via a self-administered digital questionnaire composed of items measured on a five-point Likert scale (ranging from 1 = strongly disagree/never to 5 = strongly agree/very often, depending on the item).

The instrument covered three key domains:

- **AI Competency**: Items assessed teachers' understanding of AI tools and concepts, their ability to select tools that align with instructional goals, and their skills in orchestrating and assessing AI-supported learning activities. Particular attention was given to assessment literacy, given its importance in inquiry-based instruction. A composite score was generated, with higher scores indicating greater competency.
- **AI Anxiety**: This domain captured teachers' concerns related to role shifts, workload, infrastructure reliability, academic integrity, ethical considerations, and the perceived cognitive impact of AI on students. Again, a composite score was calculated, with higher values representing greater anxiety.
- **Inquiry-Based Teaching Practices**: Items evaluated the frequency with which teachers employed structured, guided, and open forms of inquiry. Structured inquiry reflected teacher-directed approaches, guided inquiry involved shared responsibility, and open inquiry emphasized student autonomy in generating questions and designing investigations.

The questionnaire was designed to reflect both the conceptual continuum of inquiry-based learning and contemporary understandings of AI-related teaching competencies. Items were administered in a single session, with domains interleaved to reduce order effects and response bias.

Procedure

Participants received an information sheet outlining the study's purpose, their rights as participants, and assurances of confidentiality. The survey was administered online and took approximately 15–20 minutes to complete. To reduce satisficing—a tendency to answer hastily or superficially—items from different domains were mixed throughout the instrument. No monetary incentives were offered; participation was voluntary and supported by institutional encouragement.

Data Preparation and Assumptions

Prior to analysis, the dataset was screened for completeness and response plausibility. No cases were excluded due to missing data, and item-level omissions were minimal. In correlation analyses, pairwise deletion was used to retain as much data as possible without resorting to imputation.

Assumptions for inferential analyses were carefully examined:

- **Independence** was assured, as each teacher responded individually.
- **Multivariate normality** was assessed at the level of the dependent variable vectors; mild deviations were deemed acceptable given the robustness of MANOVA.
- **Homogeneity of covariance** was considered acceptable across the grouping variables.
- **Linearity** was assessed visually and conceptually; relationships among the constructs were logically appropriate and supported by observed distributions.

No data transformations were required, as all variables were reasonably symmetric and bounded.

Analytic Strategy

Data analysis unfolded in four main stages:

1. **Descriptive Statistics**: Means and standard deviations were calculated for all major constructs, providing a snapshot of teacher perceptions and behaviors.
2. **Group Differences by Location**: A two-group MANOVA tested whether AI competency and anxiety varied significantly between urban and rural teachers. Follow-up ANOVAs were used to interpret specific effects.
3. **Group Differences by Experience**: A one-way MANOVA examined the influence of teaching experience across four groups. When significant multivariate effects were found, univariate ANOVAs and group means were used to identify patterns.
4. **Correlation Analyses**: Pearson product–moment correlations were used to examine relationships between AI competency and anxiety with the three inquiry styles. These analyses explored how teachers perceived skill and concern aligned with their instructional choices.

Effect sizes were reported using partial eta squared (ηp^2) for variance analyses and Pearson's r for correlations. While no correction for multiple comparisons was applied due to the exploratory nature of the study, and interpretive caution was exercised throughout.

Findings

Descriptive Profile of Key Constructs

Table 1

Descriptive statistics for key constructs (N = 136)

Variable	M	SD	Interpretation
AI Competency	3.65	0.69	Moderate
AI Anxiety	3.24	0.64	Moderate

Note. M = mean; SD = standard deviation.

Across the full sample of 136 secondary science teachers, the data revealed a moderate level of AI competency (M = 3.65, SD = 0.69) and a similarly moderate level of AI-related anxiety (M = 3.24, SD = 0.64). Teachers generally reported feeling capable in selecting and applying AI tools within instructional settings, particularly when it came to planning and facilitating learning activities. However, confidence was noticeably lower in areas related to assessment—especially evaluating student work produced in AI-mediated contexts.

In terms of inquiry-based instruction, guided inquiry emerged as the most frequently used approach (M = 3.77, SD = 0.59), followed by structured inquiry (M = 3.68, SD = 0.66), and then open inquiry (M = 3.54, SD = 0.70). This ordering suggests that teachers tend to favor instructional formats where they retain moderate control while still allowing students to make meaningful decisions—likely due to balancing pedagogical goals with practical constraints such as time, curriculum pacing, and assessment expectations.

Table 2
Frequency of inquiry-based teaching (N = 136)

Inquiry style	M	SD	Interpretation
Structured Inquiry	3.68	0.66	Moderate
Guided Inquiry	3.77	0.59	High
Open Inquiry	3.54	0.70	Moderate

Differences by School Location

Table 3
School location effects (urban vs. rural): MANOVA and follow-up ANOVAs

Test/Outcome	Wilks' Λ / F	df	p	ηp^2	Direction
MANOVA (Competency, Anxiety)	Λ = .965; F = 2.42	2, 133	.093	—	—
Competency (ANOVA)	F = 0.195	1, 134	.659	.001	ns
Anxiety (ANOVA)	F = 4.877	1, 134	.029	.035	Rural > Urban

To explore whether school location has relationship with AI competency or anxiety, a two-group MANOVA was conducted comparing urban and rural teachers. At the multivariate level, there was no statistically significant difference (Wilks' Λ = .965, F (2, 133) = 2.42, p = .093), indicating that location did not have a connection with AI competency and anxiety.

However, follow-up univariate tests revealed a nuanced picture. While there was no significant difference in AI competency between rural and urban teachers ($F(1, 134) = 0.195$, $p = .659$, $\eta p^2 = .001$), there was a small but statistically significant difference in AI anxiety ($F(1, 134) = 4.877$, $p = .029$, $\eta p^2 = .035$). Teachers in rural settings reported higher levels of anxiety related to AI integration.

This finding underscores the impact of infrastructural variability. In rural areas, unreliable internet access, limited device availability, and reduced technical support may increase the perceived risk of failure when using AI tools during instruction. Even when teachers report comparable levels of skill, these contextual barriers can elevate anxiety.

Differences by Teaching Experience

Table 4

Teaching experience effects: MANOVA and follow-up ANOVAs

Outcome	F	df	p	ηp^2
MANOVA (Competency, Anxiety) — Wilks' Λ = .846	3.817	6, 262	.001	.080
Competency (ANOVA)	6.982	3, 132	< .001	.137
Anxiety (ANOVA)	0.324	3, 132	.808	.007

Table 5

AI competency means by teaching experience band

Experience band	M	SD (approx.)	Rank
6–10 years	3.926	~0.10	1
< 5 years	3.764	—	2
11–15 years	3.634	—	3
≥ 16 years	3.176	—	4

Teaching experience had a statistically significant multivariate effect on AI competency and anxiety (Wilks' Λ = .846, $F(6, 262) = 3.817$, $p = .001$, $\eta p^2 = .080$), suggesting that these factors vary meaningfully across different career stages.

Univariate analyses clarified that this effect was driven primarily by differences in AI competency ($F(3, 132) = 6.982$, $p < .001$, $\eta p^2 = .137$). Teachers with 6–10 years of experience reported the highest levels of competency (M ≈ 3.93), followed by those with fewer than 5 years (M ≈ 3.76), and then those with 11–15 years (M ≈ 3.63). The most experienced group (≥16 years) reported the lowest competency levels (M ≈ 3.18).

Interestingly, teaching experience had no significant effect on AI anxiety ($F(3, 132) = 0.324$, $p = .808$, $\eta p^2 = .007$), indicating that concerns about workload, role shifts, and ethical use of AI were shared across all experience levels.

Together, these findings suggest a "mid-career advantage" in AI competency. Teachers in the 6–10 year range may have enough classroom experience to confidently manage pedagogical challenges while remaining open to innovation and instructional redesign.

Associations Between Competency/Anxiety and Inquiry Practices

Pearson correlation analyses were used to examine how AI competency and anxiety related to the frequency of structured, guided, and open inquiry instruction. AI competency showed small but statistically significant positive correlations with all three types of inquiry:

Table 6
Pearson correlations between AI competency/anxiety and inquiry styles

Predictor	Structured	Guided	Open	Notes
AI Competency	.293**	.292**	.201*	* p < .05; ** p < .01
AI Anxiety	ns	ns	ns	ns = not significant

These results indicate that teachers who feel more competent in using AI are also more likely to report using inquiry-based teaching methods across the continuum from more controlled (structured) to more student-driven (open). Notably, even open inquiry, which places greater demands on both teacher and student autonomy, was positively associated with higher competency levels. By contrast, AI anxiety showed no significant correlation with any of the inquiry types (all p > .05). This suggests that, at the levels observed in this sample, anxiety does not appear to meaningfully affect whether or how teachers implement inquiry-based instruction. Several interpretations are plausible. One possibility is that teachers with sufficient competency may be able to manage or work through their anxieties. Alternatively, the levels of anxiety observed may not have been high enough to deter classroom practice. It is also possible that factors such as assessment literacy, curriculum pressure, or task design skills play a more central role in shaping teaching behavior than general attitudes toward AI.

Integrated Interpretation of Findings
Taken together, the findings highlight three key insights:

1. **Competency and anxiety are both present, but not equally influential**: While teachers reported moderate levels of both, only competency showed meaningful links to classroom practice. Anxiety, though not trivial especially in rural areas and did not appear to suppress instructional innovation on its own.
2. **Mid-career teachers are a strategic resource**: The highest levels of AI competency were found among teachers with 6–10 years of experience. These educators may be especially well-positioned to lead change efforts, mentor peers, and model AI-integrated inquiry practices.
3. **Competency is a gateway to inquiry**: Across structured, guided, and open formats, higher AI competency was associated with more frequent use of inquiry-based strategies. This suggests that efforts to increase teacher competency, particularly in task design and assessment are likely to have direct impacts on instructional quality.

Discussion

The findings from this study offer a coherent picture of how Artificial Intelligence (AI) is beginning to take root in science classrooms, and under what conditions it can support, rather than hinder, inquiry-based teaching. Broadly, the data point to a system in transition, is one where teachers are developing competence and cautiously experimenting with AI tools, but still grappling with challenges around assessment and infrastructure.

At the descriptive level, most teachers reported moderate AI competency and moderate levels of anxiety. This suggests a profession that is neither at the starting line nor fully confident. Teachers generally felt capable when it came to choosing and using AI tools, especially for planning and instruction. However, many were less confident in assessing student learning in AI-supported environments. This is consistent with a broader trend in educational technology: the final barrier to meaningful integration often lies not in access or basic usage, but in assessment that making student thinking visible and evaluating it fairly in the presence of automated assistance.

In science education, where inquiry involves exploration, modelling, and argumentation, assessment needs to capture not just what students produce, but *how* they think. Because AI tools can accelerate or automate parts of that process such as summarizing, visualizing, or generating explanations, therefore teachers face a new kind of challenge which is distinguishing between student reasoning and tool output. When assessment systems don't account for this distinction, teachers may hesitate to use AI in more open-ended tasks, sticking instead with guided or structured formats that feel more manageable.

Teaching experience emerged as another important factor. Teachers with 6–10 years of experience reported the highest levels of AI competency. These mid-career educators likely benefit from having both instructional confidence and the professional flexibility to try new approaches. In contrast, newer teachers may still be building foundational classroom routines, while more senior teachers may weigh the time and energy costs of redesigning established practices. The finding supports the idea of leveraging mid-career teachers as peer mentors or early adopters in scaling AI-integrated inquiry.

Perhaps most notably, AI competency not anxiety was the factor that predicted actual use of inquiry practices. Teachers who felt more competent were more likely to report using all three types of inquiry structured, guided, and open. Anxiety, meanwhile, showed no significant relationship with instructional behavior. This suggests that even when teachers have concerns, those with adequate skills are still willing to implement AI-supported lessons. It also implies that interventions aimed at reducing anxiety alone may not be sufficient; what matters more is equipping teachers with practical, classroom-ready skills.

However, anxiety did appear to be context-sensitive. Teachers in rural schools reported significantly higher anxiety levels than their urban counterparts. This aligns with known challenges in rural education, including unstable internet connections, limited device access, and less reliable technical support. When infrastructure is fragile, even competent teachers may feel increased pressure and risk. These contextual frictions need to be addressed if AI integration is to be equitable across settings.

The widespread preference for guided inquiry also warrants attention. This does not indicate a lack of ambition on the part of teachers, but rather a strategic balance. Guided inquiry allows students to engage in meaningful reasoning within structured parameters, while keeping classroom management, pacing, and assessment complexity within realistic bounds. Rather than positioning open inquiry as the ultimate goal, professional development should emphasize progression: helping teachers move from structured to guided and, eventually, to more open formats when conditions are right.

Assessment, again, is central. For AI to truly support inquiry, assessment strategies must be designed to distinguish scientific reasoning from mere tool usage. This includes the use of process logs, annotated explanations, oral defenses, or staged checkpoints that help

Vol. 14, No. 4, 2025, E-ISSN: 2226-6348 © 2025

surface students' thinking at various stages. Integrity concerns can be addressed not by banning AI outright, but by setting clear expectations for how it may be used and by evaluating both the process and the product of student work.

Finally, while the study's cross-sectional and self-reported nature limits causal claims, the internal consistency of the findings is compelling. The pattern is clear: building AI competency—and ensuring that teachers have the infrastructure to use it—is the most direct pathway to increasing inquiry-based instruction.

Conclusion

This study examined how secondary science teachers' AI competency and AI-related anxiety influence their use of structured, guided, and open inquiry-based teaching practices within a Malaysian educational context. Three key findings stand out.

First, most teachers reported moderate levels of both AI competency and anxiety. This indicates that the system is actively evolving and not starting from scratch, but not yet at full integration. Teachers are becoming more comfortable with AI tools, particularly in instructional planning and classroom use, but continue to face challenges with assessment in AI-mediated environments.

Second, teaching experience played a clear role in shaping AI competency. Mid-career teachers those with 6 to 10 years of experience demonstrated the highest levels of skill, suggesting they may be especially well-positioned to lead the next wave of AI-supported inquiry. By contrast, AI anxiety did not vary significantly by experience, highlighting that concerns about workload, ethics, and role changes are common across career stages.

Third, and most importantly, AI competency not anxiety was the factor most strongly associated with the use of inquiry-based instruction across all three formats. This suggests that professional development should prioritize skill-building over mindset shifts. While anxiety, particularly in rural settings, should not be ignored, it does not appear to be the main barrier to implementation. Rather, the focus should be on helping teachers build concrete, classroom-ready competencies especially in aligning AI use with valid and meaningful assessment practices.

The small but statistically significant elevation in anxiety among rural teachers underscores the importance of addressing systemic inequities in infrastructure and support. Without reliable internet access, adequate devices, and responsive technical assistance, even skilled teachers may hesitate to use AI tools for inquiry, particularly when the risks of lesson failure are high.

Future research should build on this foundation through longitudinal and design-based studies. These could test whether gains in AI assessment literacy predict sustained increases in inquiry-based instruction and improvements in student reasoning. Similarly, equity-focused interventions, particularly those pairing infrastructure upgrades with instructional coaching could yield high-impact results in underserved rural contexts.

In sum, this study offers a clear message: competency is the lever, and context is the runway. When teachers have the skills to design, facilitate, and assess AI-enhanced inquiry and when schools provide the conditions for success, AI becomes a genuine partner in fostering the kind of disciplined curiosity and scientific thinking that science education aspires to cultivate.

References

Azlida, M., Suzieleez Syrene, A. R., Sulaiman, T., & Baki, R. (2015). Relationship between critical thinking disposition and inquiry teaching style among science teachers. *Advanced Science Letters, 21*(7), 2336–2339. https://doi.org/10.1166/asl.2015.6268

Kementerian Pendidikan Malaysia. (2023). *Dasar Pendidikan Digital (Digital Education Policy).* Kementerian Pendidikan Malaysia. https://www.moe.gov.my/storage/files/shares/Dasar/Dasar%20Pendidikan%20Digital/Digital%20Education%20Policy.pdf dl.acm.org

Min, T., Lee, B., & Jho, H. (2025). Integrating generative artificial intelligence in the design of scientific inquiry for middle school students. *Education and Information Technologies.* Advance online publication. https://doi.org/10.1007/s10639-025-13410-1 Frontiers

Mohd Majid. (2005). *Kaedah pengkajian pendidikan* (Edisi ke-7). Dewan Bahasa dan Pustaka.

Mohd Najib Abdul Ghafar. (2003). *Reka bentuk tinjauan soal selidik pendidikan.* Skudai, Johor: Penerbit Universiti Teknologi Malaysia (UTM).

Muhd Al-Aarifin, I., & Jamilah Al-Muhammady, M. (2017). Kahoot: A promising tool for formative assessment in medical education. *Education in Medicine Journal, 9*(2), 19–26. https://doi.org/10.21315/eimj2017.9.2.2 SpringerLink

Norlela, S. (2017). Enhancing scientific literacy through implementation of inquiry-based science education (IBSE) in Malaysia science curriculum. *International Journal of Academic Research in Business and Social Sciences, 7*(2), 769. https://doi.org/10.6007/IJARBSS/v7-i2/2685 *(DOI sudah disediakan oleh anda.)*

Nur Faizahton, S., Azimah, N., Bukhari, M., & Yue, W. S. (2022). Pembelajaran berasaskan inkuiri dalam meningkatkan kemahiran literasi sains dan pencapaian murid menerusi persekitaran pembelajaran dalam talian. *Malaysian Journal of Social Sciences and Humanities (MJSSH), 7*(1), 73–84. https://doi.org/10.47405/mjssh.v7i1.1250 mail.msocialsciences.com

Nur Sakinah, Z., & Melor, M. Y. (2023). Teachers' perceptions and continuance usage intention of artificial intelligence technology in TESL. *International Journal of Multidisciplinary Research and Analysis, 6*(5), 2101–2109. https://doi.org/10.47191/ijmra/v6-i5-34 ResearchGate+1

Ouahi, M. B., Lamri, D., Hassouni, T., & Al Ibrahmi, E. M. (2022). Science teachers' views on the use and effectiveness of interactive simulations in science teaching and learning. *International Journal of Instruction, 15*(1), 277–292. https://doi.org/10.29333/iji.2022.15116a jotse.org

Pallant, J. (2020). *SPSS survival manual* (5th ed.). Routledge.

Pan, M., Wang, J., & Wang, J. (2023). Application of artificial intelligence in education: Opportunities, challenges, and suggestions. Dalam *Proceedings of the 2023 13th International Conference on Information Technology in Medicine and Education (ITME)* (pp. 623–627). IEEE. https://doi.org/10.1109/ITME60234.2023.00130 SpringerLink+1

Paramasveran, R., & Nurfaradilla, M. N. (2018). Teachers' concerns on the implementation and practices of i-THINK with Concern Based Adoption Model (CBAM). *Creative Education, 9*(14), 2183–2191. https://doi.org/10.4236/ce.2018.914159 SCIRP

Piaget, J. (1976). Piaget's theory. Dalam B. Inhelder, H. H. Chipman, & C. Zwingmann (Pnyt.), *Piaget and his school* (pp. 11–23). Springer. https://doi.org/10.1007/978-3-642-46323-5_2 SpringerLink

Poobalan, N., Zaharudin, R., & Ting Voon, Y. (2019). Penggunaan bahan multimedia interaktif 3D animasi ('Scratch') dalam kaedah pembelajaran teradun terhadap minat dan pencapaian murid Tahun 5 bagi mata pelajaran Sains. *Jurnal Pendidikan Sains dan Matematik Malaysia, 9*(1), 49–56. https://doi.org/10.37134/jpsmm.vol9.1.6.2019 ejournal.upsi.edu.my

Radif, M. (2024). Artificial intelligence in education: Transforming learning environments and enhancing student engagement. *Educational Sciences: Theory and Practice, 24*(1), 93–103. https://doi.org/10.12738/jestp.2024.1.008 openurl.ebsco.com+1

Ramesh, M. R. (2025). Challenges of integrating artificial intelligence with language curriculum (pp. 205–230)

Revuelta-Domínguez, F. I., Guerra-Antequera, J., González-Pérez, A., Pedrera-Rodríguez, M. I., & González-Fernández, A. (2022). Digital teaching competence: A systematic review. *Sustainability, 14*(11), 6428. https://doi.org/10.3390/su14116428 MDPI

Ridwan, H., Sutresna, I., & Haryeti, P. (2019). Teaching styles of the teachers and learning styles of the students. *Journal of Physics: Conference Series, 1318*, 012028. https://doi.org/10.1088/1742-6596/1318/1/012028 Academia