The Relationship Between Scientific Knowledge, Scientific Attitudes, and Teaching Experience among Malaysian Science Teachers

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DOI: https://dx.doi.org/10.47772/IJRISS.2025.903SEDU0638

Received: 15 October 2025; Accepted: 22 October 2025; Published: 13 November 2025

ABSTRACT

Strengthening scientific literacy among teachers is a critical lever for improving science education quality and achieving national STEM aspirations. In Malaysia, ongoing curriculum reforms and assessment demands heighten the need to understand not only teachers' factual scientific knowledge but also their scientific attitudes and how these dimensions vary across career stages. This study examines scientific literacy among primary science teachers by focusing on (a) factual scientific knowledge, (b) scientific attitudes, (c) differences in attitudes by teaching experience, and (d) the association between knowledge and attitudes. A structured questionnaire was administered to 59 teachers in Kuala Lumpur, and data were analysed using SPSS (v27). Overall factual knowledge was high, with item-level correct response rates predominantly exceeding 80%. Scientific attitudes were likewise high ($M = 4.63$, $SD = 0.40$). A one-way ANOVA indicated significant differences in attitudes across teaching-experience categories, with teachers in the 6–10-year band reporting the lowest mean score ($M = 4.40$) relative to other groups ($M = 4.64–4.80$), $F(3,55) = 3.30$, $p = .03$. Pearson's correlation revealed a modest but statistically significant negative relationship between knowledge and attitudes ($r = –.319$, $p = .014$). The findings underscore the importance of career stage–responsive professional development, pedagogical approaches that integrate attitudinal objectives with content mastery, and the systematic incorporation of scientific literacy competencies into in-service training.

Keywords: scientific literacy, teacher knowledge, scientific attitudes, teaching experience, primary science education, Malaysia

INTRODUCTION

Scientific literacy, defined as the ability to apply scientific knowledge and inquiry processes to interpret everyday phenomena, make informed decisions, and engage meaningfully in civic discourse, has been conceptualised in contemporary literature as a multidimensional construct. This construct integrates conceptual understanding, competencies in scientific inquiry, and dispositions such as curiosity, openness to evidence, and confidence in addressing uncertainty (Bybee, McCrae, and Laurie, 2009; Lederman, Lederman, and Antink, 2013; Costa, Loureiro, and Ferreira, 2021).

For educators, these dimensions are mutually reinforcing. A strong foundation in scientific content enables accurate explanation and pedagogical clarity, while the presence of constructive scientific attitudes fosters a classroom culture that promotes inquiry, evidence-based argumentation, and reflective judgment. In the Malaysian context, efforts to enhance scientific literacy among teachers are further necessitated by national aspirations for science, technology, engineering, and mathematics (STEM) education, such as the 60 to 40 policy target favouring science and technical streams over arts. Additionally, international assessment frameworks continue to underscore persistent challenges in students' scientific literacy (Kementerian Pendidikan Malaysia, 2016; PISA-related reporting).

Primary science teachers, who frequently represent students' initial sustained exposure to formal science education, hold a critical role in nurturing both foundational scientific concepts and the epistemic and affective dispositions associated with scientific thinking. Their pedagogical decisions regarding emphasis, handling of uncertainty, and framing of evidence are influenced not only by their knowledge base but also by their attitudes towards science as a mode of understanding the world. However, the empirical literature within the Malaysian context offers limited integrated analyses that examine both teachers' factual knowledge and their scientific attitudes concurrently. Existing studies often focus solely on content knowledge or pedagogical content knowledge, without explicit consideration of teacher attitudes, or conversely, assess attitudes and beliefs without anchoring them in objective measures of factual knowledge (cf. Buma and Sibanda, 2022; Maulina, Hamid, and Halim, 2019; Cheng, Talib, and Othman, 2019).

This disjunction leaves unresolved important questions regarding whether teachers with stronger factual knowledge also exhibit stronger scientific attitudes, and whether variations in career stage influence this relationship. These questions are especially relevant in light of increased workload and accountability demands.

The theoretical foundation of this study is informed by a social cognitive framework, wherein teacher learning and practice are understood to emerge from the dynamic interaction of personal factors (such as knowledge, attitudes, and self-efficacy), environmental conditions (including curricula, assessment practices, and school culture), and enacted behaviours (such as lesson design, discursive practices, and assessment strategies) (Barkha Devi, Khandelwal, and Das, 2017).

Within this framework, scientific attitudes are considered not incidental but rather essential dispositions that enable educators to navigate ambiguity, evaluate competing explanations, and facilitate student engagement in evidence-based reasoning. Importantly, teaching experience is posited to influence the expression of these dispositions. Teachers in the early stages of their careers may prioritise procedural accuracy and curriculum coverage. Those in the middle stages often encounter increased administrative and instructional responsibilities that may limit opportunities for inquiry-based teaching. In contrast, more experienced educators may reach a stage of professional recalibration that emphasises meaning-making and student-centred discourse. Furthermore, international findings that the relationship between knowledge and attitudes is not universally positive provide additional impetus for this investigation (Lee and Kim, 2019).

Empirically, this study addresses existing gaps through a district-level survey conducted among primary science teachers in Sentul, Kuala Lumpur. The study design encompasses three components: first, the measurement of factual scientific knowledge using true or false items aligned with key concepts from the primary science curriculum; second, the assessment of scientific attitudes through a validated Likert-scale instrument designed to capture dispositions related to inquiry, evidence, and openness to alternative explanations; and third, the analysis of differences in scientific attitudes across varying levels of teaching experience, along with the correlation between knowledge and attitudes. The instruments utilised for data collection were adapted from previous research and underwent rigorous expert validation and pilot testing to ensure their clarity, relevance, and reliability prior to full implementation (Misbahul Jannah, 2016; Mohd Radzi Abu Bakar, 2021; Ghazali and Sufean, 2016; Rosinah, 2012; Pallant, 2013).

This study contributes to the field in three key ways. Conceptually, it advances the understanding of scientific literacy by treating it as an integrated construct, wherein both knowledge and attitudes are assessed simultaneously. Methodologically, it employs validated instruments and appropriate statistical analyses to capture levels of and relationships between variables, while also considering variations across stages of the teaching career. Practically, the findings offer actionable recommendations for professional development, including content reinforcement, support for cultivating positive scientific attitudes, and the strategic timing of interventions throughout the teacher career continuum (Lederman et al., 2013; Bybee et al., 2009).

In particular, should the data reveal a decline in scientific attitudes during certain career stages, this would underscore the need for targeted support strategies aimed at sustaining inquiry-oriented dispositions during periods characterised by heightened administrative and assessment demands.

THEORETICAL AND CONCEPTUAL BACKGROUND

Contemporary conceptualisations of scientific literacy emphasise its multifaceted nature, in which knowledge, competencies, attitudes, and contextual elements function interdependently within authentic problem-solving contexts. Rather than viewing these attributes in isolation, recent scholarship argues that scientific literacy emerges through the integration of conceptual understanding with inquiry practices that are situated within real-world settings (Bybee, McCrae, and Laurie, 2009; Lederman, Lederman, and Antink, 2013). This integrated perspective foregrounds not only what individuals know, but how they apply that knowledge in dynamic, evidence-driven reasoning.

Within this framework, scientific attitudes are not limited to general favourability toward science. Rather, they are viewed as functional dispositions that facilitate inquiry-oriented engagement. These include curiosity, openness to alternative explanations, commitment to evidentiary reasoning, and trust in methodological safeguards such as experimental controls, replication, and peer critique (Costa, Loureiro, and Ferreira, 2021). Such dispositions are instrumental in fostering classrooms where inquiry and critical thinking are valued and practiced.

A social cognitive perspective offers explanatory power for understanding how these domains of knowledge, attitude, and context interact in actual teaching environments. Specifically, teaching practice is conceptualised as emerging from reciprocal interactions among environmental affordances (including resources, time constraints, and assessment frameworks), personal factors (such as beliefs about the nature of science and self-efficacy), and enacted behaviours (including task design, discourse patterns, and assessment strategies) (Bandura, 1986; Barkha Devi, Khandelwal, and Das, 2017).

Within such educational ecologies, teachers' knowledge and attitudes jointly mediate how instructional constraints are perceived and navigated. Conversely, persistent environmental pressures may either suppress or enable the expression of inquiry-supportive attitudes, even when teachers possess strong content knowledge. This view aligns with research that positions scientific inquiry and an understanding of the nature of science as central components of scientific literacy (Lederman et al., 2013; Duschl and Grandy, 2013).

Teaching experience is likely to moderate these dynamics, as different career stages bring distinct expectations and workload profiles. For instance, early-career teachers often prioritise procedural accuracy, curriculum coverage, and classroom management. Mid-career teachers may assume broader responsibilities, such as administrative and mentoring duties, which in turn reduce opportunities for open-ended inquiry. Later in their careers, teachers may stabilise their routines and shift their focus back toward meaning-making and student discourse (Huberman, 1989; Lee and Kim, 2019). Empirical evidence supports the notion that attitudes toward teaching science evolve over time, thereby highlighting the importance of considering career stage in analyses of teacher practice (Maulana, Opdenakker, and Bosker, 2016).

These theoretical and empirical considerations inform two working assumptions in the present study. First, knowledge and attitudes are conceptually distinct and non-redundant. While accurate content knowledge is essential for effective science instruction, it is not sufficient for inquiry-rich pedagogy. Structural constraints such as limited instructional time, pressure from assessment regimes, and behavioural management demands may dampen the outward expression of curiosity, openness, and cautious reasoning, even among well-informed educators (Gess-Newsome, 2015; Park and Chen, 2012). This is consistent with research demonstrating that teachers' knowledge, beliefs, and instructional practices are shaped as much by contextual demands as by individual capacity.

Second, career stage mediates both pedagogical enactment and instructional climate. The same level of content knowledge may be applied differently depending on the teacher's stage in the profession, while attitudinal dispositions may strengthen or weaken as professional responsibilities evolve over time (Day and Gu, 2007). Importantly, international analyses reveal that the relationship between scientific knowledge and attitudes is not consistently positive (Lee and Kim, 2019), which further justifies examining experience as a potential moderating variable.

Collectively, this theoretical architecture comprising multidimensional scientific literacy, the reciprocal dynamics of social cognitive theory, and teaching experience as a moderating factor that frames the empirical strategy of the present study. Specifically, the research seeks to (a) measure factual scientific knowledge and scientific attitudes concurrently, (b) compare attitudinal profiles across different experience levels, and (c) examine whether the association between knowledge and attitude is conditional rather than universal. These aims are aligned with recent calls in the literature to conceptualise scientific literacy in teacher education as an integrated outcome that encompasses content knowledge, inquiry practices, and attitudinal dispositions (Bybee et al., 2009; Lederman et al., 2013).

Research Design and Context

This study employed a cross-sectional survey design to characterise primary science teachers' scientific literacy in terms of factual scientific knowledge and scientific attitudes, and to examine (a) differences in attitudes by teaching experience and (b) the association between knowledge and attitudes. The study site was the Sentul district of Kuala Lumpur, comprising national primary schools operating under the national curriculum.

Participants and Sampling

Participants were 59 in-service primary science teachers recruited from district schools. Eligibility criteria included (i) current appointment as a science teacher and (ii) at least one academic year of teaching experience. Participation was voluntary with informed consent. Table 1 summarises the distribution of teaching experience.

Table 1. Participant profile by teaching experience (N = 59)

Teaching experience	N	%
0–5 years	9	15.3
6–10 years	16	27.1
11–15 years	12	20.3
16–20 years	22	37.3

Instruments

The questionnaire comprised three sections: (1) demographics (including years of teaching), (2) a 10-item factual scientific knowledge test (true/false), and (3) a 10-item scientific attitudes scale (five-point Likert: 1 = strongly disagree to 5 = strongly agree).

Factual knowledge. Items targeted core primary science concepts (e.g., ecology, environmental issues, physical geography) aligned with curriculum emphases. Item analysis from the underlying project indicates acceptable difficulty and discrimination at the pilot stage.

Scientific attitudes. The scale assessed inquiry-oriented dispositions (e.g., curiosity, openness to alternative explanations, evidentiary reasoning, comfort with methodological safeguards). Internal consistency was excellent (Cronbach's α = 0.976). Corrected item–total correlations exceeded .30.

Table 2. Measurement quality

Construct	k	Example content focus	Reliability / quality indices
Factual scientific knowledge	10	Primary science concepts (true/false)	Mean item difficulty ≈ 0.73; mean discrimination ≈ 0.25
Scientific attitudes	10	Curiosity; openness; evidence use (Likert 1–5)	Cronbach's α = 0.976; all item–total r > .30

Procedures and Ethical Considerations

Permission for school access was secured via the relevant education authorities. Instruments underwent expert review and piloting for clarity and contextual fit. Data collection was conducted during scheduled school hours with minimal disruption. Respondents were briefed on study objectives, voluntariness, and confidentiality; no identifying information was reported.

Data Preparation and Screening

Responses were entered into SPSS (v27). Data screening covered completeness checks, outlier inspection, and verification of scale directions. For inferential analyses, assumptions were examined:

1. Normality. Histograms and skewness/kurtosis for knowledge and attitude composites were within acceptable ranges for the planned parametric tests.
2. Homogeneity of variance. Levene's test for the attitudes ANOVA was inspected (based on means).
3. Independence. Sampling and administration procedures supported independence across respondents.

Analytic Strategy

Analyses proceeded in four steps:

1. Descriptive statistics for knowledge (item-level correct %) and attitudes (M, SD).
2. Group differences in attitudes by experience using one-way ANOVA, followed by Scheffé post hoc comparisons (unequal group sizes). Partial eta squared (ηp^2) was computed as an effect-size index.
3. Bivariate association between knowledge and attitudes using Pearson's correlation (two-tailed). The coefficient of determination (r^2) and Fisher's z confidence interval were calculated for interpretive clarity.
4. Measurement checks were summarised to document reliability and item functioning.

FINDINGS

Measurement Quality

The attitudes scale exhibited excellent internal consistency (α = 0.976). Knowledge items demonstrated acceptable psychometric characteristics at the pilot stage, with mean item difficulty around 0.73 and mean discrimination around 0.25, supporting their use for descriptive purposes.

Table 3. Knowledge test: item-level performance

Item	Correct (%)
B1	76.3
B2	94.9
B3	81.4
B4	94.9
B5	76.3
B6	89.8
B7	91.5
B8	83.1
B9	96.6
B10	94.9

RQ1—What is the level of teachers' factual scientific knowledge?

Item-level accuracy was high, with most items exceeding 80% correct and several above 90% (Table 3). The two comparatively lower items (B1, B5) still exceeded three-quarters correct, suggesting specific, not systemic, content refresh targets.

RQ2—What is the level of teachers' scientific attitudes?

Scientific attitudes were high overall (M = 4.63, SD = 0.40), aligning with an interpretive "high" band (3.81–5.00). Distributional checks were acceptable for parametric analyses.

Table 4. Scientific attitudes: overall descriptive statistics

Measure	n	Mean	SD	Range (observed)
Attitudes (10 items; 1–5)	59	4.63	0.40	High band

RQ3—Do scientific attitudes differ by teaching experience?

A one-way ANOVA indicated significant between-group differences, $F(3, 55) = 3.30$, $p = .03$. The effect size (partial ηp^2) was approximately 0.153, indicating a small-to-moderate practical effect. Post hoc comparisons (Scheffé) showed that teachers with 6–10 years of experience reported significantly lower attitudes than other groups.

Table 5. Attitudes by teaching experience

Experience	n	Mean
0–5 years	9	4.77
6–10 years	16	4.40
11–15 years	12	4.80
16–20 years	22	4.64

Table 6. One-way ANOVA summary for attitudes

Source	df	SS	MS	F	p	ηp^2
Between groups	3	—	—	3.30	.03	0.153
Within groups	55	—	—	—	—	—
Total	58	—	—	—	—	—

Interpretation. The profile is consistent with a career-stage dip in attitudes among mid-career teachers (6–10 years), relative to both early-career and later-career peers. From a professional learning perspective, this pattern suggests targeted supports that preserve inquiry-oriented dispositions during mid-career role expansion.

RQ4—What is the relationship between knowledge and scientific attitudes?

Pearson's correlation indicated a modest but statistically significant negative relationship between factual knowledge and scientific attitudes, $r = -.319$, $p = .014$ (two-tailed, $N = 59$). The shared variance was approximately 10.2% ($r^2 \approx .102$). A Fisher's z 95% confidence interval placed the correlation between –0.532 and –0.069, indicating the negative association is small-to-moderate in magnitude but unlikely to be zero in this sample.

Table 7. Correlation between factual knowledge and scientific attitudes

Variables	r	p	95% CI (Fisher's z)	r^2
Knowledge ↔ Attitudes	–0.319	.014	[–0.532, –0.069]	0.102

Interpretation. The negative association suggests that greater factual command does not automatically translate into stronger attitudinal endorsement of inquiry-related dispositions under prevailing contextual constraints. Plausible explanations include assessment-driven prioritisation, opportunity costs that limit inquiry talk and exploration, and ceiling or compression effects given generally high levels on both constructs.

DISCUSSION

Interpreting High Levels of Factual Knowledge and Scientific Attitudes

The finding that primary science teachers reported both high levels of factual scientific knowledge and strong endorsement of scientific attitudes is consistent with global literature that characterises professional educators as generally well-informed regarding foundational scientific concepts while concurrently expressing positive orientations toward scientific inquiry (Osborne, Simon, and Collins, 2003; Kind, 2014). The elevated levels of factual knowledge observed in this sample are likely attributable to sustained engagement with the national curriculum, recurrent exposure to content through cyclical syllabus reviews, and routine participation in school-based assessments that prioritise canonical accuracy (Shulman, 1986; Abell, 2007).

Similarly, the presence of favourable scientific attitudes among participants aligns with previous research demonstrating that many educators, regardless of implementation challenges, value student-centred inquiry, argumentation, and evidence-based reasoning (National Research Council [NRC], 2012; Lederman and Lederman, 2014). When considered in tandem, these findings suggest that, at least within the studied district, teachers possess both the cognitive resources and the dispositional orientations necessary to support inquiry-rich science instruction. This dual capacity is essential for the development of students' scientific literacy, which requires not only accurate content delivery but also pedagogical practices that foster curiosity, reasoning, and engagement with the nature of science (Bybee, 2014; OECD, 2019).

Interpreting the Mid-Career Dip in Scientific Attitudes

The significant decline in scientific attitudes observed among teachers with 6 to 10 years of experience warrants particular attention. This pattern invites interpretation through the lens of career-stage development models, which suggest that early-career teachers often focus on survival, procedural fidelity, and classroom management; mid-career educators typically assume expanded administrative, mentoring, and leadership responsibilities; and late-career professionals tend to stabilise their practice, often integrating more reflective and meaning-centred approaches (Huberman, 1989; Day and Gu, 2007).

Within this developmental arc, mid-career teachers may experience increased role strain and workload intensification, which, in turn, reduce the cognitive and temporal space available for sustaining inquiry-based instruction. This hypothesis is supported by empirical research showing that effective inquiry teaching requires time, flexibility, and a supportive institutional climate—resources that may be especially constrained for teachers in the middle phase of their careers (OECD, 2020; Kang and Wallace, 2005). As such, the observed attitudinal decline may reflect not diminished commitment to scientific principles but the adaptive recalibration of instructional priorities under institutional pressure (Bandura, 1986; Coburn, 2004).

Two mechanisms are particularly salient in explaining this phenomenon. First, the scarcity of instructional time: inquiry-based pedagogical strategies, such as facilitating discourse, eliciting multiple explanations, and guiding students through argumentation with evidence, require sustained classroom time that mid-career teachers may lack due to added professional responsibilities (Windschitl, Thompson, and Braaten, 2008). Second, the pressure to align instruction with high-stakes assessment regimes: where performance metrics focus primarily on curriculum coverage and test accuracy, teachers may reasonably prioritise efficiency and compliance, thereby reducing the frequency of exploratory, student-driven learning experiences (Au, 2007; Smith and Southerland, 2007). The observed recovery in attitudinal scores among later-career teachers corresponds with international evidence suggesting that motivation, efficacy, and identity can improve when teachers develop greater instructional fluency and professional autonomy (Day and Gu, 2007; Klassen and Chiu, 2010).

Understanding the Negative Correlation Between Knowledge and Attitudes

The modest yet statistically significant negative correlation between factual knowledge and scientific attitudes, although counterintuitive, can be interpreted through several plausible explanatory frameworks. Traditional theories posit a mutually reinforcing relationship between content knowledge and positive orientations toward science (Osborne et al., 2003; Bybee, 2014). However, the present findings suggest that this relationship may be more complex and context-dependent.

One possible explanation is an opportunity-cost dynamic. Teachers who possess stronger content expertise may be more frequently tasked with leadership responsibilities such as setting examinations or aligning instruction with curricular standards. These roles may incentivise pedagogical choices that favour breadth and correctness over depth and inquiry, thereby limiting opportunities to engage in the types of discourse associated with strong scientific attitudes (Coburn, 2004; Au, 2007).

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume IX Issue XXVI October 2025 | Special Issue on Education

A second explanation concerns psychometric ceiling and compression effects. Given that both knowledge and attitudes were high overall in this sample, restricted variance in one construct can lead to apparent inverse correlations when the other remains more normally distributed. This statistical artefact is well documented in high-performing samples and does not necessarily indicate a substantive negative relationship (Cohen, Cohen, West, and Aiken, 2003).

A third interpretation draws on the epistemic sophistication paradox. As teachers deepen their content knowledge, they may also develop heightened awareness of uncertainty, ambiguity, and the limitations of oversimplified scientific investigations. This epistemic humility, while pedagogically valuable, may reduce self-reported confidence or lead to more cautious responses on attitudinal measures, particularly those involving perceived efficacy or generalisation (Hofer and Pintrich, 1997; Sandoval, 2005).

Finally, discrepancies in measurement alignment may contribute to the observed association. The knowledge instrument used in this study primarily assessed factual accuracy through true or false questions, whereas the attitudinal scale targeted dispositions related to inquiry, evidentiary reasoning, and open-ended exploration. In contexts where educational performance is rewarded based on speed and correctness rather than exploratory learning, stronger knowledge may coexist with relatively constrained attitudinal expression (Windschitl et al., 2008; NRC, 2012).

It is important to emphasise that none of these interpretations imply that content knowledge undermines scientific attitudes. Rather, they highlight the importance of ecological and institutional context in shaping the interaction between these domains, in accordance with social cognitive theory (Bandura, 1986).

Implications for Professional Learning and School Design

The findings of this study carry important implications for the design of professional learning programmes and school-level policy interventions. A differentiated, stage-sensitive approach to teacher development appears warranted.

For early-career teachers, professional development should integrate content reinforcement with structured rehearsal of inquiry routines. Pedagogical strategies such as claim–evidence–reasoning, collaborative sensemaking, and guided discourse should be introduced early to normalise the language and practices of scientific inquiry (McNeill and Krajcik, 2012; Osborne, 2014). For mid-career educators, support should emphasise efficiency and sustainability. Micro-inquiries aligned with curriculum goals, streamlined rubrics that highlight evidentiary reasoning without inflating grading demands, and explicit protection of discourse time during lessons may help mitigate the pressures that suppress inquiry-oriented practice (Hattie and Clarke, 2019; Shavelson, Ruiz-Primo, and Wiley, 2005). For experienced teachers, professional learning could focus on mentorship and the diffusion of effective inquiry practices through peer coaching and professional learning communities (Korthagen, 2017).

At the systemic level, three strategic levers are especially pertinent:

Assessment alignment: Policy frameworks should prioritise tasks and assessment items that reward evidence-based reasoning, thus reducing the perceived conflict between inquiry and accountability (NRC, 2012; Pellegrino, Chudowsky, and Glaser, 2001).

Collaborative structures: School-based inquiry initiatives such as lesson study or professional learning communities (PLCs) can be leveraged to co-design lessons, anticipate pacing constraints, and reduce the cognitive burden associated with individual lesson planning (Lewis, 2002; Vescio, Ross, and Adams, 2008).

Leadership signals: Observation frameworks and instructional feedback tools should explicitly value scientific discourse, student argumentation, and the strategic use of representations. These signals can help recalibrate instructional priorities and legitimise the time required for inquiry-based teaching (Danielson, 2013; Osborne, 2014).

Positioning the Findings Within the Malaysian Policy Context

Malaysia's educational policy agenda, particularly regarding STEM education and scientific literacy, has consistently emphasised the dual importance of conceptual mastery and inquiry competence. National curriculum documents and strategic plans articulate a vision in which students are not only knowledgeable about scientific facts but also capable of engaging in evidence-based reasoning and investigation (Kementerian Pendidikan Malaysia, 2016; OECD, 2019).

The current findings suggest that many primary science teachers already demonstrate the foundational knowledge and attitudinal orientation necessary to support such a vision. However, career-stage variations in scientific attitudes indicate that systemic and institutional factors may constrain the enactment of inquiry-based teaching. As such, modest yet strategic interventions such as aligning assessments with inquiry outcomes, reducing non-instructional workload during mid-career, and investing in coaching to support classroom discourse could yield substantial improvements in teaching quality without requiring fundamental changes to curriculum or policy structures (Hattie, 2009; NRC, 2012).

CONCLUSION

This study set out to investigate the relationship between factual scientific knowledge and scientific attitudes among primary science teachers in a Malaysian district, with particular attention to variation across career stages. Drawing on a social cognitive framework and an integrated view of scientific literacy, the study contributes to the growing literature that treats knowledge, attitudes, and contextual factors as interdependent elements of science teaching practice.

Empirical findings revealed that teachers in the sample reported high levels of both factual knowledge and scientific attitudes, suggesting that the foundational cognitive and dispositional resources required for inquiry-based instruction are broadly present. However, the study also identified a noteworthy decline in attitudinal endorsement among mid-career teachers, a pattern consistent with theoretical models positing increased workload, administrative responsibilities, and role strain during this phase of professional development. The negative correlation observed between factual knowledge and scientific attitudes, although modest, further underscores the need to consider how institutional ecologies shape the enactment of inquiry practices, even among knowledgeable educators.

These findings carry several implications for policy and practice. Most notably, they support the call for career-stage-responsive professional learning that aligns with teachers' evolving responsibilities and constraints. Providing early-career teachers with structured opportunities to embed inquiry routines, supporting mid-career educators through time-efficient and contextually aligned inquiry tools, and leveraging the expertise of later-career teachers as mentors represent promising strategies for sustaining positive attitudes and inquiry-rich instruction throughout the teaching career.

At the system level, the results point to the importance of aligning assessment policies, leadership signals, and collaborative structures with the broader aims of scientific literacy. Rather than focusing solely on curricular reform, policymakers and school leaders may achieve greater impact by recalibrating instructional incentives and reducing environmental constraints that suppress inquiry practices.

Future research should extend this analysis across broader geographic and institutional contexts to examine the generalisability of the observed patterns. Longitudinal studies that track teachers over time could offer deeper insights into how knowledge and attitudes co-evolve and how interventions at different career stages influence professional trajectories. Furthermore, mixed-methods research that incorporates classroom observations and teacher reflections could help clarify the mechanisms by which attitudes are translated into practice under varying ecological conditions.

In sum, this study affirms that fostering scientific literacy in classrooms depends not only on what teachers know, but also on how they feel about science, how they navigate professional demands, and how the system enables or constrains the enactment of inquiry. Supporting teachers across the arc of their careers is therefore not merely a matter of professional development, but a structural imperative for science education reform.

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