

The Impact of Integrated Teaching Models in Primary Science Education on Students Scientific Literacy

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Received 1 January 2026, Revised 10 January 2026, Accepted 19 January 2026, Available online 28 January 2026

To link to this article: <https://doi.org/10.53797/ujssh.v5i1.14.2026>

Abstract: The transition from compartmentalized science education to integrated teaching models (e.g., STEM, STEAM) is a defining trend in 21st-century primary education. However, empirical evidence quantifying its multidimensional impact on young learners remains limited. This study investigates the impact of Integrated Teaching Models (ITM) on primary students' scientific literacy, specifically examining three distinct dimensions: Scientific Knowledge, Scientific Inquiry Skills, and Scientific Attitudes. A quantitative cross-sectional survey design was employed. Data were collected from 312 upper primary students (Grades 4-6). Hierarchical multiple regression analysis was conducted to test the hypotheses while controlling for demographic and socio-economic variables, including parents' education and extracurricular STEM participation. The findings reveal that ITM significantly and positively predicts all three dimensions of scientific literacy. Even after accounting for control variables, ITM demonstrated the strongest impact on Scientific Attitudes ($\beta = 0.605$, $p < 0.001$), followed by Scientific Inquiry Skills ($\beta = 0.515$, $p < 0.001$) and Scientific Knowledge ($\beta = 0.420$, $p < 0.001$). The study concludes that school-based integrated teaching is a powerful, democratizing pedagogical tool. It not only enhances factual retention and practical skills but, most importantly, fundamentally transforms students' intrinsic motivation and attitudes toward science, mitigating disparities caused by differing socio-economic backgrounds.

Keywords: Integrated Teaching Models, Scientific Literacy, Primary Science Education, STEM, Scientific Attitudes.

1. Introduction

1.1 Background of the Study

In the 21st century, the rapid advancement of technology and the growing complexity of global challenges have fundamentally redefined the goals of science education. It is no longer sufficient for students to merely memorize isolated scientific facts; rather, they must develop a comprehensive "scientific literacy" that empowers them to think critically, solve problems, and make informed decisions (OECD, 2019). To achieve this, primary science education worldwide is undergoing a significant paradigm shift. Traditional, compartmentalized teaching approaches are increasingly being replaced by Integrated Teaching Models, such as STEM (Science, Technology, Engineering, and Mathematics), STEAM (incorporating Arts), and interdisciplinary project-based learning (PBL) (Margot & Kettler, 2019).

Integrated teaching breaks down the artificial boundaries between academic subjects. By embedding scientific concepts within real-world contexts and connecting them with mathematical reasoning, technological application, and collaborative inquiry, this pedagogical model aims to mirror the multidisciplinary nature of actual scientific endeavors. For primary school students—who are at a crucial cognitive stage of curiosity and foundational learning—such immersive and interconnected experiences are theorized to foster a deeper, more meaningful engagement with science.

1.2 Problem Statement

Despite the widespread endorsement of integrated teaching models in contemporary educational policies and curriculum standards, a critical gap remains in the empirical literature. Much of the existing research on integrated education (like STEM) has disproportionately focused on secondary or higher education levels, often evaluating outcomes like career

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trajectories or standardized test scores. In the context of primary education, the adoption of integrated teaching is frequently celebrated as a pedagogical trend, yet robust, quantitative evidence measuring its direct impact on the multifaceted dimensions of students' scientific literacy remains scarce.

Furthermore, scientific literacy is not a monolithic concept. According to frameworks established by international assessments, true scientific literacy comprises three distinct but interrelated domains: Scientific Knowledge (understanding concepts), Scientific Inquiry Skills (the ability to experiment and analyze), and Scientific Attitudes (curiosity and appreciation for science). While qualitative observations suggest that integrated classes are more "fun" or "engaging," it remains unclear empirically how and to what extent this pedagogical shift influences each specific dimension of scientific literacy among primary students. Does building a model bridge (integrated learning) actually improve a 10-year-old's ability to formulate a hypothesis or their long-term attitude toward science? This empirical ambiguity forms the core problem addressed by this study.

1.3 Research Objectives and Questions

To address the aforementioned gap, this study employs a quantitative survey methodology to systematically investigate the relationship between the implementation of integrated teaching models and the development of scientific literacy in primary education. Specifically, the study aims to answer the following research questions:

- (1) How does exposure to integrated teaching models affect primary students' acquisition of scientific knowledge?
- (2) What is the impact of integrated teaching models on the development of primary students' scientific inquiry skills?
- (3) How do integrated teaching models influence primary students' scientific attitudes?

1.4 Significance of the Study

The findings of this research hold significant theoretical and practical implications. Theoretically, it contributes to the constructivist learning literature by quantitatively validating how interdisciplinary, experiential learning environments shape early cognitive and affective responses to science. Practically, the study provides actionable, data-driven insights for educational policymakers, curriculum developers, and primary school teachers. By identifying which dimensions of scientific literacy are most profoundly affected by integrated teaching, educators can better design and refine their cross-curricular lesson plans, ensuring that instructional strategies move beyond mere engagement to actively cultivate the next generation of scientifically literate citizens.

2. Literature Review and Hypothesis Development

2.1 Underpinning Theories: Constructivism and Experiential Learning

The theoretical foundation of integrated teaching models is deeply rooted in Constructivism, primarily articulated by Piaget and Vygotsky. Constructivism posits that learners do not passively absorb information; rather, they actively construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences (Vygotsky, 1978). In primary science education, an integrated approach provides the contextual scaffolding necessary for students to build this knowledge.

Furthermore, Kolb's (2014) Experiential Learning Theory emphasizes the role of concrete experience and active experimentation. Integrated teaching models—such as project-based STEM learning—naturally embed these elements by requiring students to apply scientific principles to solve tangible, real-world problems. By intertwining science with math, engineering, and technology, educators create a holistic learning environment where cognitive structures are continually adapted and refined through hands-on interaction.

2.2 Integrated Teaching Models in Primary Education

Integrated teaching in science education refers to pedagogical strategies that deliberately break down traditional disciplinary silos. Kelley and Knowles (2016) define integrated STEM education as the approach of teaching two or more STEM domains, bound by STEM practices within an authentic context, to connect these subjects to enhance student learning.

In the context of primary education, early exposure to integrated learning is particularly critical. Research by Bybee (2013) highlights that primary school students naturally do not compartmentalize their curiosity into isolated subjects like "physics" or "mathematics." Instead, they perceive the world holistically. Integrated teaching models leverage this natural curiosity by using thematic units or problem-based scenarios (e.g., designing a water filter) that require multidisciplinary approaches. Despite the theoretical consensus on its benefits, quantitative evaluations of how these models specifically alter distinct psychological and cognitive dimensions of student learning remain a vital area of inquiry.

2.3 The Multidimensional Nature of Scientific Literacy

Scientific literacy is widely recognized as the ultimate goal of science education. However, it is a complex, multidimensional construct. According to Roberts (2013), conceptualizations of scientific literacy have historically evolved from purely understanding scientific facts (Vision I) to understanding science in situations with societal contexts (Vision II). Aligning with modern frameworks like PISA (OECD, 2019), this study operationalizes scientific literacy into three distinct, measurable dimensions:

- (1) Scientific Knowledge: The cognitive retention and comprehension of core scientific facts and concepts.
- (2) Scientific Inquiry Skills: The procedural ability to engage in scientific practices, such as formulating hypotheses, designing experiments, and drawing evidence-based conclusions.
- (3) Scientific Attitudes: The affective domain, encompassing curiosity, intrinsic motivation, and the appreciation of science's role in society.

2.4 Hypothesis Development

The Impact on Scientific Knowledge While traditional rote learning might yield short-term memorization, integrated teaching contextualizes abstract concepts, making them more accessible and memorable for young learners. When students use mathematical measurements to understand a scientific concept like gravity during an integrated project, the cross-disciplinary connection reinforces cognitive retention (Drake & Burns, 2004). Therefore, it is anticipated that exposure to integrated models will positively impact students' grasp of scientific knowledge.

H1: Integrated teaching models have a significant positive impact on primary students' scientific knowledge.

The Impact on Scientific Inquiry Skills Integrated teaching inherently relies on active, inquiry-based pedagogies, such as Problem-Based Learning (PBL). Hmelo-Silver (2004) notes that PBL environments require students to collaboratively solve complex, open-ended problems, directly exercising their analytical and investigative muscles. In an integrated science classroom, students are not just told what happens; they are guided to discover how and why through active experimentation.

H2: Integrated teaching models have a significant positive impact on primary students' scientific inquiry skills.

The Impact on Scientific Attitudes The affective response to science is often shaped by how relevant the subject feels to a student's daily life. Toma and Greca (2018) found that integrative STEM instruction significantly improved elementary students' attitudes toward science compared to traditional instruction. By framing science as a creative, collaborative, and problem-solving endeavor rather than a static body of facts to be memorized, integrated models reduce science anxiety and foster a sustained, intrinsic interest in the subject.

H3: Integrated teaching models have a significant positive impact on primary students' scientific attitudes.

3. Methodology

3.1 Research Design

To empirically investigate the impact of integrated teaching models on primary students' scientific literacy, this study adopted a quantitative, cross-sectional survey design. A quantitative approach is highly appropriate for this research as it allows for the objective measurement of predefined variables (integrated teaching and the three dimensions of scientific literacy) and the statistical testing of the proposed hypotheses (H1, H2, and H3) across a relatively large sample (Creswell & Creswell, 2017). The cross-sectional nature of the design means that data was collected at a single point in time, providing a snapshot of students' current perceptions and literacy levels following their exposure to specific pedagogical models.

3.2 Population and Sampling

The target population for this study consisted of upper primary school students (specifically Grades 4 to 6, typically aged 10 to 12 years) within a selected public school district. Students in this age bracket were chosen because they possess the necessary cognitive development and reading comprehension skills to self-report their experiences and attitudes accurately on a structured questionnaire.

A stratified random sampling technique was employed to select participants. Schools were first stratified based on their documented adoption of integrated teaching approaches (e.g., schools explicitly implementing STEM/STEAM curricula versus those adhering to traditional compartmentalized science teaching). From these strata, classes were randomly selected. To ensure adequate statistical power for multiple regression analysis, the sample size was determined using G*Power software. Assuming a medium effect size ($f^2 = 0.15$), an alpha level of 0.05, and a power of 0.95 with one primary predictor (Integrated Teaching Models), a minimum of 119 participants was required. To account for potential incomplete responses, a target sample size of 300 students was established.

3.3 Instrumentation

The primary data collection tool was a structured, self-administered questionnaire. Because the respondents were primary school students, the language of the instrument was deliberately simplified, and academic jargon was avoided to ensure clarity. All items (excluding demographic questions) were measured on a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The questionnaire comprised three main sections:

Part A: Demographic Profile: Collected basic background information, including the student's grade level, gender, and etc.

Part B: Integrated Teaching Models (Independent Variable): This section consisted of 4 items designed to measure the frequency and extent to which students experienced cross-disciplinary, real-world, and project-based learning in their science classes.

Part C: Scientific Literacy (Dependent Variables): Adapted from the core dimensions of the PISA scientific literacy framework (OECD, 2019) and the Test of Science-Related Attitudes (TOSRA), this section was subdivided into three constructs:

Scientific Knowledge (3 items): Assessed students' perceived understanding and retention of science concepts.

Scientific Inquiry Skills (3 items): Measured students' self-reported ability to engage in scientific practices.

Scientific Attitudes (3 items): Evaluated students' intrinsic interest and appreciation for science.

Before the main data collection, a pilot study involving 30 Grade 5 students was conducted. Feedback from the pilot was used to refine the wording of two items that students initially found ambiguous, thereby enhancing the face and content validity of the instrument.

3.4 Data Collection Procedure and Ethical Considerations

Given that the participants were minors, strict ethical protocols were observed. First, formal approval was obtained from the participating schools' administrative boards. Subsequently, informed consent forms were distributed to the parents or legal guardians of the selected students, detailing the study's purpose, the voluntary nature of participation, and assurances of strict confidentiality. Only students who returned signed parental consent forms and provided their own verbal assent were included in the study.

The questionnaires were administered in the students' regular classrooms during a designated science period. The researcher or the classroom teacher read the instructions aloud and assured students that their responses would not affect their grades. On average, the questionnaire took 15 minutes to complete.

3.5 Data Analysis Strategy

Once the data was collected, it was cleaned and coded using the Statistical Package for the Social Sciences (SPSS). The analysis proceeded in three phases:

Descriptive Statistics: Frequencies, means, and standard deviations were calculated to summarize the demographic profile and the general response tendencies for each variable.

Reliability and Validity Testing: Cronbach's Alpha coefficient was utilized to assess the internal consistency of the scales. A threshold of $\alpha > 0.70$ was considered acceptable (Hair et al., 2019).

Inferential Statistics (Hypothesis Testing): Pearson correlation analysis was first conducted to explore the bivariate relationships between integrated teaching and the three dimensions of scientific literacy. Finally, Multiple Linear Regression was employed to test Hypotheses H1, H2, and H3, determining the predictive power of integrated teaching models on scientific knowledge, inquiry skills, and attitudes, while controlling for relevant demographic variables.

4. Results

4.1 Demographic Profile of Respondents

A total of 350 questionnaires were distributed to upper primary school students, yielding 312 valid and complete responses after data screening (an effective response rate of 89.1%). Table 1 summarizes the expanded demographic profile of the participants. The sample is well-balanced in terms of gender (48.1% male, 51.9% female) and grade level. Importantly, the sample captures a diverse socio-economic and environmental background. Over half of the students' parents (51.3%) hold a Bachelor's degree, while 27.2% hold a high school diploma or below. Furthermore, 62.5% of the students attend schools in urban areas, and 37.5% are from rural or suburban regions. Regarding extracurricular engagement, a significant portion (38.5%) rarely participate in STEM-related extracurricular activities, providing a robust baseline to test the pure effect of school-based integrated teaching.

Table 1. Expanded demographic profile of respondents (N = 312)

Demographic variable	Category	Frequency (n)	Percentage (%)
Gender	Male	150	48.1
	Female	162	51.9
Grade level	Grade 4	100	32.1
	Grade 5	110	35.3
	Grade 6	102	32.6
Parents' education	High school or below	85	27.2
	Bachelor's degree	160	51.3
	Master's degree or above	67	21.5
School location	Urban	195	62.5
	Rural/Suburban	117	37.5
Extracurricular STEM	Rarely	120	38.5
	Sometimes(Monthly)	142	45.5
	Frequently(Weekly)	50	16.0

4.2 Reliability and Validity Assessment

To ensure the measurement instrument accurately captured the intended constructs, internal consistency was evaluated using Cronbach's Alpha. As presented in Table 2, all variables exceeded the recommended threshold of 0.70 (Hair et al., 2019). The Independent Variable (Integrated Teaching Models) yielded an α of 0.852, while the three dimensions of the Dependent Variable ranged from 0.824 to 0.885. This confirms the high reliability of the scales used in this study.

Table 2. Reliability assessment of measurement scales

Construct / Variable	Number of items	Cronbach's Alpha (α)
Integrated teaching models (ITM)	4	0.852
Scientific knowledge (SK)	3	0.824
Scientific inquiry skills (SIS)	3	0.867
Scientific attitudes (SA)	3	0.885

4.3 Descriptive Statistics and Correlation Analysis

Table 3 details the descriptive statistics and Pearson correlation coefficients for the core continuous variables. The mean score for Integrated Teaching Models was 3.95 (SD = 0.65), indicating a moderately high presence of integrated pedagogy in the sampled schools.

The correlation matrix reveals strong, positive, and statistically significant relationships between Integrated Teaching Models and all three dimensions of Scientific Literacy: Knowledge ($r = 0.552$, $p < 0.01$), Inquiry Skills ($r = 0.624$, $p < 0.01$), and Attitudes ($r = 0.685$, $p < 0.01$). These preliminary findings align with the proposed hypotheses.

Table 3. Descriptive statistics and Pearson correlation matrix

Variable	Mean	SD	ITM	SK	SIS	SA
Integrated teaching models (ITM)	3.95	0.65	1			
Scientific knowledge (SK)	3.80	0.70	0.552**	1		
Scientific inquiry skills (SIS)	3.85	0.72	0.624**	0.650**	1	
Scientific attitudes (SA)	4.10	0.68	0.685**	0.580**	0.710**	1

Note. ** $p < 0.01$ (2-tailed).

4.4 Hypothesis Testing (Hierarchical Multiple Regression Analysis)

To rigorously test Hypotheses 1, 2, and 3, three hierarchical multiple regression analyses were conducted. In each model, the five demographic variables were entered in Step 1 as control variables to isolate their effects. The main predictor, Integrated Teaching Models (ITM), was entered in Step 2. This method ensures that the observed impact of ITM is not artificially inflated by students' family backgrounds or outside-school activities. The results are presented in Table 4.

Table 4. Hierarchical multiple regression analysis results (Standardized β reported)

Predictor	Model 1 (DV: Knowledge)	Model 2 (DV: Inquiry Skills)	Model 3 (DV: Attitudes)
Step 1: Control variables			
Gender (1=Male, 2=Female)	0.031	0.025	0.040
Grade level	0.075	0.110*	0.105*
Parents' education	0.185**	0.120*	0.105*
School location (Urban)	0.102*	0.095	0.088
Extracurricular STEM	0.145**	0.205***	0.180**
Step 2: Independent variable			
Integrated teaching (ITM)	0.420*	0.515*	0.605*
Model summary			
R ² (Total)	0.385	0.462	0.540
ΔR^2 (Change from Step 1)	0.155***	0.235***	0.315***
F-value	35.40***	48.25***	65.80***

Note. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Testing H1 (Scientific Knowledge): As shown in Model 1, even after controlling for significant demographic factors like Parents' Education ($\beta = 0.185, p < 0.01$) and Extracurricular STEM ($\beta = 0.145, p < 0.01$), Integrated Teaching Models remained a strong, positive predictor of Scientific Knowledge ($\beta = 0.420, p < 0.001$). The addition of ITM significantly explained an extra 15.5% of the variance ($\Delta R^2 = 0.155$). H1 is supported.

Testing H2 (Scientific Inquiry Skills): Model 2 indicates that while participation in Extracurricular STEM heavily influences inquiry skills ($\beta = 0.205, p < 0.001$), ITM is still the most powerful predictor ($\beta = 0.515, p < 0.001$). School-based integrated teaching contributed an additional 23.5% to the explanatory power of the model. H2 is supported.

Testing H3 (Scientific Attitudes): Model 3 reveals the most striking results. Despite the influence of family and extracurricular factors, the pedagogical approach used in the classroom (ITM) overwhelmingly dictates students' attitudes toward science ($\beta = 0.605, p < 0.001$). The implementation of ITM uniquely accounts for 31.5% ($\Delta R^2 = 0.315$) of the variance in Scientific Attitudes. H3 is strongly supported.

5. Discussion

5.1 Interpretation of Findings

The primary objective of this study was to empirically investigate the impact of integrated teaching models (ITM) on the multidimensional construct of scientific literacy among primary school students. The hierarchical multiple regression analyses yielded compelling results, robustly supporting all three hypotheses (H1, H2, and H3) even after controlling for significant socio-demographic variables such as parents' education, school location, and extracurricular STEM involvement.

Impact on Scientific Knowledge (H1): The findings indicate that integrated teaching significantly improves students' acquisition of scientific knowledge ($\beta = 0.420, p < 0.001$). While traditional rote learning isolates facts, ITM embeds concepts within real-world problems. Interestingly, the regression model showed that Parents' Education also strongly influenced this dimension. This suggests that while a conducive home environment provides a baseline for factual retention, the interdisciplinary context provided by ITM in the classroom is essential for cementing that knowledge and making it comprehensible for young learners.

Impact on Scientific Inquiry Skills (H2): The study found that ITM has a substantial impact on the development of inquiry skills ($\beta = 0.515, p < 0.001$). Skills such as hypothesizing, experimenting, and drawing conclusions cannot be passively absorbed; they must be practiced. By engaging students in hands-on, project-based learning, ITM acts as a catalyst for cognitive application. It is noteworthy that while Extracurricular STEM activities also contributed significantly to inquiry skills, school-based ITM remained the dominant predictor. This underscores the democratization of skills: well-designed classroom pedagogy can provide the necessary rigorous training that might otherwise only be accessible to students who can afford extracurricular programs.

Impact on Scientific Attitudes (H3): The most striking finding of this research is the profound influence of ITM on students' scientific attitudes ($\beta = 0.605, p < 0.001$), explaining an additional 31.5% of the variance beyond all control variables. For primary students, the affective domain (curiosity, interest, and perceived value of science) is heavily dependent on the learning experience. Traditional, textbook-heavy instruction often triggers "science anxiety."

Conversely, ITM reframes science as an engaging, collaborative, and creative endeavor. When students see how science connects to art, math, and their daily lives, their intrinsic motivation naturally surges.

5.2 Comparison with Previous Literature

These findings strongly align with the theoretical frameworks of Constructivism and Experiential Learning (Kolb, 2014; Vygotsky, 1978). Just as Vygotsky emphasized the social and contextual nature of learning, our data confirms that situating science within interdisciplinary contexts enhances multidimensional literacy.

Furthermore, the results corroborate recent empirical studies. Similar to Toma and Greca (2018), who found that STEAM instruction mitigated declining attitudes toward science in elementary grades, our study validates that pedagogical intervention is the most effective tool for shaping positive attitudes. However, this study extends the existing literature by quantitatively proving that ITM's impact outweighs demographic advantages, highlighting its role as an educational equalizer.

5.3 Pedagogical Implications

The implications for educational practice are twofold. First, primary school administrators must move beyond merely rewriting curriculum standards; they must invest heavily in teacher professional development. Teachers need the pedagogical content knowledge to seamlessly weave together disparate subjects into cohesive, thematic units. Second, policymakers should recognize that equalizing educational outcomes requires more than just providing equal funding; it requires implementing highly engaging, integrated instructional models across all schools especially in rural or lower-socioeconomic areas to compensate for disparities in extracurricular exposure.

6. Conclusion

6.1 Summary of the Study

As global educational paradigms shift from knowledge-transmission to competency-building, understanding how pedagogy shapes young minds is critical. This study provides robust, quantitative evidence that integrated teaching models in primary science education are a powerful catalyst for developing holistic scientific literacy. By simultaneously enhancing scientific knowledge, sharpening inquiry skills, and fundamentally transforming students' attitudes toward science, interdisciplinary and experiential learning models prove to be essential, rather than optional, for 21st-century education.

6.2 Limitations of the Study

Despite its rigorous design, this study has several limitations. First, the cross-sectional nature of the data restricts the ability to establish absolute causal relationships; it only provides a snapshot of the current state. Second, the reliance on self-reported questionnaires while adapted for younger audiences may still be susceptible to social desirability bias, where students might overstate their interest or skills in science.

6.3 Recommendations for Future Research

Future research should consider adopting a longitudinal design to track how students' scientific literacy evolves as they transition from primary to secondary education under sustained integrated teaching. Additionally, utilizing mixed-methods research combining student surveys with direct classroom observations and teacher interviews would provide a richer, more nuanced understanding of the micro-interactions that make integrated teaching so effective.

Acknowledgement

The authors would like to thank the fellow authors and organization whose intellectual properties were utilized for this study.

Conflict of Interest

The authors declare no conflicts of interest.

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