Full research paper

BREAKING DOWN BARRIERS: TEACHERS' ATTITUDES TOWARDS TRANSITIONING FROM SPECIALIZATION TO INTEGRATED SCIENCE EDUCATION

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ABSTRACT

Even though integrated science education (ISE) has been advocated globally for decades to enhance students' scientific literacy, developing countries with their own contextual conditions still face ongoing struggles in transitioning from subject specialization to integration. To ensure educational efficiency, specifically by reducing disciplinary fragmentation and optimizing resource use, understanding teachers' attitudes, along with diverse contextual factors, plays a pivotal role in the ISE movement. This quantitative study examines the attitudes of Vietnamese science teachers at various school levels, emphasizing differences in their attitudes across contextual variables, which informs strategies to enhance ISE promotion. The questionnaire-based methodology was employed to collect 203 responses, and the data were analyzed using one-way ANOVA. Our findings proved that (1) science teachers favored ISE despite the obstacles and anxiety of an educational reform; (2) traditional assumptions of contextual variables such as gender, years of teaching experience, and educational qualifications do not statistically differ in teachers' attitudes; (3) the quality of professional development might relate to teachers' perceived difficulty, anxiety, and self-efficacy towards ISE. Therefore, a sustainable, high-quality provision of professional development is essential to help teachers achieve ISE instructional objectives, alongside more practical solutions.

KEYWORDS

Contextual factors, educational efficiency, education reform, integrated science, integrated teaching, teachers' attitudes,

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Highlights

- *Despite constant struggles during the transition from subject specialization to integration, science teachers favored integrated science education (ISE).*
- *Traditional assumptions about contextual variables such as gender, years of teaching experience, and educational qualifications do not hold for teachers' attitudes.*
- *The quality of professional development is strongly associated with teachers' perceived difficulty, anxiety, and self-efficacy towards ISE, serving as a critical determinant of the educational efficiency of the ISE reformed curriculum.*

INTRODUCTION

Since the beginning of the 20th century, the United Nations Educational, Scientific, and Cultural Organization has widely advocated *integrated science education (ISE)* to deliver more meaningful educational experiences that improve students' conceptual understanding and the application of knowledge (Åström, 2008; Wei, 2020). Integration refers to the systematic organization of diverse subject matter into a cohesive framework that reflects how humans think and act; it involves designing educational programs that break traditional boundaries between fields of study, presenting them as a unified subject that focuses on innovation using modern tools and technologies and the applied process to solve complex problems (Åström, 2008; Bati, 2023; Kelley and Knowles, 2016). Transitioning from subject specialization to integration deems essential because it reflects the premise that science is a dynamic methodology for understanding natural phenomena and the crosscutting concepts in all science disciplines, such as seeking patterns in data, or cause and effect relationships, rather than a rigid

collection of disparate subject-specific facts, hypotheses, and rules to be memorized and applied (Bastian and Fortner, 2018). To be more specific, unlike the subject-area specialization approach in science education, a transformative ISE encompasses (a) the integration of appropriate technology and engineering within the science and mathematics curriculum; (b) the promotion of scientific inquiry and engineering design, alongside rigorous mathematics and science instruction; (c) collaborative learning approaches that connect students and teachers across science fields and professionals; (d) the provision of global and multi-perspective viewpoints; and (e) the incorporation of strategies such as project-based learning, offering both formal and informal learning experiences to enhance learning (Kennedy and Odell, 2014).

The advantages and disadvantages of this transformation, however, remain contentious. On the one hand, specialization had a negative impact on school student achievement, especially in mathematics (Fryer, 2018). On the other hand, ISE has been claimed to provide students with a more cohesive grasp of complex real-world phenomena, enhancing not only their conceptual understanding but also 21st-century skills such as critical thinking and problem-solving, while boosting their engagement with school and interest in science subjects (Guerrero and Reiss, 2020; Kucuk, 2023; Li et al., 2020). Teachers' varied interpretations and approaches to integration are largely responsible for challenges associated with ISE implementation, including fluctuations in students' performance and motivation, increased teachers' workload, inefficiencies in infrastructure, and pedagogical, material, curricular and professional development limitations, concerns over inconsistent and unsubstantiated student assessments, teacher qualifications, and teacher shortages (Margot and Kettler, 2019; Pham et al., 2023; Thuan and Mau, 2021).

In these circumstances, science teachers and their attitudes towards ISE are playing a crucial role as primary catalysts for educational reforms because they are adopting ISE that goes beyond traditional science subjects, integrating innovative methods into science instruction, and simultaneously providing insights into resistance to change (Haatainen et al., 2021; Pillai et al., 2022; Strat et al., 2024). In 2023, Tytler et al. (2023) cautioned that disregarding teachers' attitudes and belief systems poses a significant risk to innovators' ability to sustain ISE deployment, as positive attitudes lead to success, while negative attitudes lead to failure and avoidance. Since then, little is known about teachers' attitudes, particularly those in developing countries and underrepresented groups striving to catch up with developed countries, and the contextual factors that shape them, such as gender, years of teaching, and professional development (Winarno, 2020). More importantly, recent reviews emphasize that contextual factors do not operate in isolation but interact with broader systemic influences, such as curriculum reforms, examination pressures, and the availability of instructional resources, to shape teachers' perceptions and practices (Shahali and Halim, 2024). Yet, few empirical studies have investigated these dynamics in developing countries, where the transition to ISE is particularly complex due to under-resourced school environments, limited teacher preparation, and top-down policy reforms (Pham et al., 2023; Vu, 2021). This lack of systematic evidence leaves unanswered questions about how contextual factors collectively relate to teachers' attitudes and whether certain factors are more dominant than others.

The case of Vietnam, a developing country, highlights this issue because its long-standing subject-specialized curriculum, combined with a high-stakes examination culture and chronic shortages of instructional resources, has made the transition to integrated science particularly challenging for teachers. In Vietnam, the 12-year national curriculum was originally structured to include physics, chemistry, and biology as separate subjects, delivered primarily through didactic lecturing. Beyond localized, small-scale projects, there was no experience with a comprehensive ISE. The high-stakes, examination-based educational system relies on assessing each subject in isolation. While this approach ensures a solid foundation in theoretical knowledge and technical accuracy, it can limit opportunities for hands-on experimentation, inquiry-based learning, and creativity in classroom practice. Moreover, many schools lack sufficient laboratory equipment, digital tools, and interdisciplinary teaching materials, making it difficult for teachers to design lessons that integrate science, technology, engineering, and mathematics in practical ways (Curtis, 2021). Until 2018, the Ministry of Education and Training introduced an integrative approach into the national curriculum to facilitate learners' comprehension of scientific principles, permit systematic problem-solving in an interdisciplinary manner, and promote informed decision-making, thereby promoting sustainable development of applied sciences and solving real-world problems (Bodewig et al., 2014; Doan, 2020).

However, Vietnamese science teachers seem to have expressed reluctance to adopt ISE, citing the primary cause of a lack of policy and training guidance during the transition and implementation of this approach across K-12 levels (Nguyen and Pham, 2021; Pham et al., 2023; Vu, 2021). Nguyen et al. (2020) argued that Vietnamese teachers' adoption of new integrated science instruction methods depends on understanding the various underlying contextual factors that influence their teaching behaviors, including years of experience, educational background, and the subjects they teach. Despite the initiation of ISE years earlier, Vietnamese students performed below the Organization for Economic Co-operation and Development average in the 2022 PISA science assessment. In order to remedy this problem, the Ministry of Education and Training (2023) temporarily experimented with co-teaching instruction, yet left in-service teachers without a vision for, or understanding of, how to develop high-quality, genuinely integrated lessons or curricula.

The current study seeks to address a significant gap in the body of research on educational contexts in developing countries, such as Vietnam, where limited attention has been given to the attitudinal responses of K–12 Vietnamese science teachers toward ISE. This focus is particularly critical given the absence of systematic investigations into their perspectives on both current practices and forthcoming trends during this pivotal transition to ISE. The research will also consider the contextual factors related to teachers' attitudes, alongside practical recommendations. The research questions are as follows:

RQ1:What are Vietnamese science teachers' attitudes toward teaching integrated science education (ISE)?

RQ2: What contextual factors shape Vietnamese science teachers' attitudes toward teaching integrated science education (ISE)?

LITERATURE REVIEW

Teachers' attitudes towards implementing integrated science education across K-12 levels

Science teachers' attitudes have been recognized as a key factor in determining the success of educational reform, shaping their ethical or unethical intentions and influencing their instructional practices in terms of frequency, quality, and content (Mâță et al., 2020). Attitudes are also claimed to guide teachers' actual classroom practices, including the acceptance of new approaches, techniques, and changes in their practices, often resulting from alterations in their attitudes (Thibaut et al., 2018). However, the definition or construct of "attitudes" varies across studies, as the term may refer to teachers' internal personal reinforcement, such as their emotional dispositions and cognitive perceptions (e.g., classified as good or bad), or to their external, dynamic, and reciprocal psychological interactions with students, encompassing perceived control and classroom management ideologies (e.g., positive or negative concepts underlying instructional behaviors) (Bandura, 1986).

Recent researchers (e.g., van Aalderen-Smeets et al., 2012; Thibaut et al., 2019; Pryor et al., 2016; Shidiq and Faikhamta, 2020) thus opted for a holistic definition that includes all the aforementioned constructs as complementary dimensions. Specifically, Pryor et al. (2016) explained that attitudes are shaped by the interplay between the perceived strength of intentions or beliefs about the likely outcomes of a behavior and the self-evaluation of those outcomes as they materialize, reflecting the actualization of those beliefs. They reported that high intenders had more favorable attitudes toward ISE and were likelier than low intenders to implement it. Likewise, Shidiq and Faikhamta (2020) stated that attitude is one of the personality aspects that can be influenced by the individual's internal feelings, such as cognition, knowledge, values, motivation, and self-efficacy, which refers to a person's belief in their ability to control these factors when translating them into real-world behavior.

Thibaut et al. (2018, 2019) conceptualized attitude more precisely through the Three-Component Model, which comprises three dimensions that predict and govern behavior: (1) the *cognitive component, referring to an individual's thoughts and opinions about the attitude object*; (2) the *affective component, involving the emotions or feelings associated with the attitude object*; and (3) the *perceived control component, reflecting the actions or responses of the individual when engaging with the attitude object*. Thibaut et al. (2018, 2019) indeed conducted a more detailed analysis of each dimension based on the work of van Aalderen-Smeets et al. (2012). They validated the subscales of teachers' attitudes toward teaching science. These subscales included two cognitive subscales, "perceived relevance" and "perceived difficulty" of teaching ISE, two subscales of teachers' affective states, "enjoyment" and "anxiety," and two subscales of perceived control, "self-efficacy" and "context dependency." Respectively, they defined the key terms as follows. Perceived relevance and perceived difficulty indicate the extent to which the community of science teachers considers ISE pertinent, practical, and challenging. Anxiety reflects the extent to which teachers experience stress, apprehension, or discomfort when teaching. High levels of anxiety may hinder a teacher's confidence and willingness to engage with ISE, thereby influencing their instructional behaviors and the overall success of ISE implementation. Self-efficacy refers to an individual's belief in their ability to successfully perform specific tasks or achieve desired outcomes in a given context. Thus, it encompasses teachers' confidence in mastering interdisciplinary content, applying innovative teaching methods, and managing classroom dynamics effectively. A high sense of self-efficacy empowers teachers to overcome challenges, adapt to diverse teaching contexts, and foster meaningful student engagement in ISE. Context dependency in the construct of attitudes refers to the extent to which teachers' attitudes are influenced by external contextual factors. These factors may include institutional policies, resource availability, support from colleagues or administrators, class size, curriculum design, or the socio-cultural environment in which teaching occurs.

The current study aligns with such a holistic definition of recent studies and employs the framework of attitudes developed by van Aalderen-Smeets et al. (2012), entailing the same dimensions. However, this study made a minor modification by excluding the "enjoyment" subscale. Although "enjoyment" is relevant, it is less critical to understanding actionable factors like perceived relevance, difficulty, anxiety, and self-efficacy, which directly yield explanatory power regarding teachers' resistance to change. Thibaut et al. (2017) also showed that "enjoyment" is strongly correlated with "self-efficacy" and thus provides less actionable insights compared to "anxiety."

Contextual factors related to teachers' attitudes toward integrated science education

Contextual factors have been influential in shaping teachers' attitudes, experiences, and adaptability to change, as well as their support and enthusiasm for schoolwide ISE initiatives (Mellati et al., 2015; Thibaut et al., 2019). Specifically, research found that teachers' gender, teaching experience, and education level are positively correlated with their attitudes (Al Salami et al., 2017; Margot and Kettler, 2019).

Specifically, female teachers have been found to have a more negative view of ISE education, specifically incorporating technology to implement it, than male teachers (Park et al., 2016). Although the incursion of women and girls into new technologies and science facilitates the elimination of the discrimination they have suffered, female teachers scored higher than their male colleagues on both the pretest and posttest in terms of their motivation to use Information and Communication Technology tools in ISE (Palomares-Ruiz et al., 2020). Still, while numerous studies have demonstrated significant disparities regarding attitudes between male and female teachers, others have observed minimal differences or even parallels in the general attitudes of both gender groups (e.g., Thibaut et al., 2019; Tweed, 2013).

The second component under consideration is teaching experience, typically measured by the number of years of professional experience. It is assumed that, over time, teachers accumulate mastery experiences, which contribute to enhanced self-efficacy, a component of attitudes (Bandura, 1986, 1997). Prior research has revealed a somewhat negative correlation between years of teaching experience and various aspects of teachers' perceptions of integrated STEM (Science, Technology, Engineering, and Mathematics) education (Thibaut et al., 2018, 2019). Especially

given the limited number of role models who were experienced teachers with ISE, teachers in individual disciplines did not seem to have enough experience with integrated learning. In other words, while teachers may have spent years teaching their own subject matter, they had limited experiential knowledge and resources for envisioning what integrated science lessons should and could look like (Ryu et al., 2019).

Nonetheless, Kalliontzi (2022) reported no significant associations between demographic factors, such as gender and years of teaching experience, and teachers' beliefs or their implementation of integrated STEM practices. However, the study highlighted that certain characteristics, most notably higher levels of education (e.g., holding a master's degree) and specific age groups, were positively related to teachers' beliefs and their willingness to adopt an integrated approach. These findings suggest that while some commonly examined demographic variables may exert limited influence, advanced academic preparation and life-stage factors can play a meaningful role in shaping teachers' dispositions toward integrated STEM instruction.

Similarly, teachers' professional development is closely linked to their years of teaching experience. During the implementation of the education reform, professional development sessions are regarded as a fundamental tool for content delivery and must thus be understood. Literature indicates that the provision of professional development is positively connected with teachers' attitudes, improving teachers' self-efficacy beliefs regarding ISE, feeling less dependent on context factors, enjoying science teaching, and decreasing anxiety (Aldahmash et al., 2019; Dinh and Nguyen, 2023; Thibaut et al., 2019; van Aalderen-Smeets and Walma van der Molen, 2015) and can beneficially alter those previous negative viewpoints on ISE before the training (Al Salami et al., 2017; Nadelson et al., 2013). Professional development also greatly benefits science teachers to deploy ISE, as they may possess a positive attitude but often face challenges in understanding the concept of integration and its practical applications (Parmin et al., 2020). Even so, professional development has not consistently yielded the anticipated advantages for science teachers. Tweed (2013) conducted research revealing no substantial impact of professional development on teachers' self-efficacy.

Another characteristic is the teachers' educational backgrounds and qualifications. Teachers with varied academic backgrounds may display differing attitudes owing to ISE approaches. Prior studies reveal statistical differences in the perspectives of master's and undergraduate teachers regarding ISE (Clark et al., 2014). In contrast, Thibaut et al. (2019) examined this component; nevertheless, their results indicated no significant correlations between master's degrees and teachers' perceptions. In Vietnam, many teachers pursue master's degrees or higher qualifications due to salary incentives (Linh and Bell, 2024), so it would be advantageous to analyze the relationship between undergraduate and graduate programs and their role in shaping teachers' qualifications.

Lastly, research indicated a correlation between school/grade levels and teachers' psychological metrics, including attitudes. For instance, there exists a statistically negligible variation in teachers' opinions across various grade levels (Hackman et al., 2021), yet most research focuses on primary, secondary, and high schools' levels rather than higher education (Margot and Kettler, 2019), so minimal research elucidated the impact of this element on the overall attitudes of teachers, particularly in the domain of ISE.

The literature review establishes that determining the factors that shape attitude formation is crucial to the effective implementation of integrated science in educational reform. This study addresses this by examining both general attitudes toward integrated science and the impact of teachers' background characteristics and contextual factors. Altogether, Figure 1 illustrates the conceptual constructs of attitudes and five subscales related to three dimensions of attitudes, together with pertinent background or contextual factors influencing teachers' attitudes.

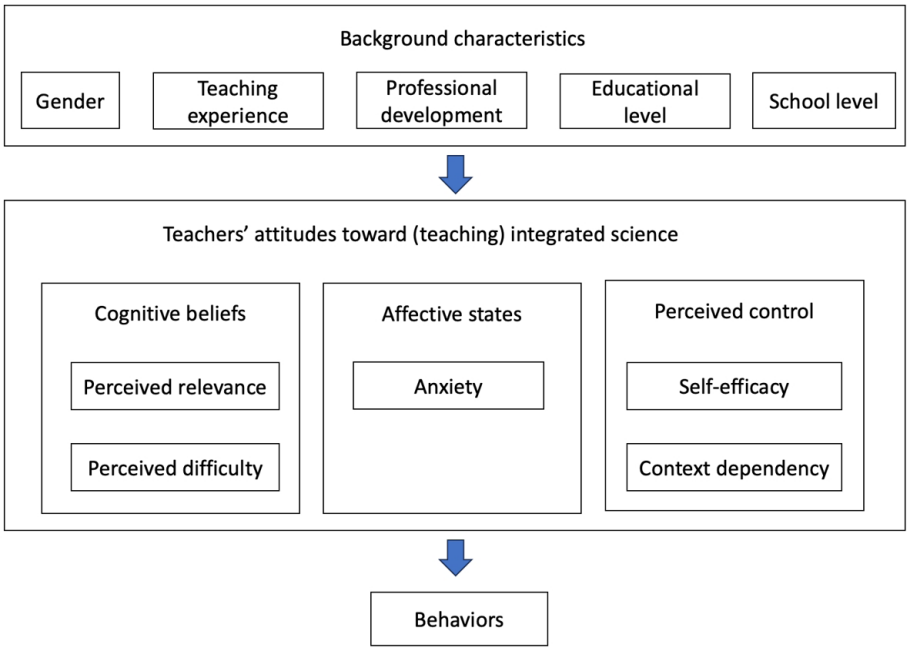

Figure 1: Theoretical Framework of Teachers' Attitudes toward ISE (Thibaut et al., 2018, 2019) and Background Factors

MATERIALS AND METHODS

Research design and sample

This study employed a questionnaire-based methodology to examine Vietnamese science teachers' attitudes toward Integrated Science Education (ISE) and to analyze demographic factors associated with their responses, thereby informing strategies for effective educational reform. According to Vaziri and Mohsenzadeh (2012), a questionnaire-based methodology enables the efficient collection of data from a large and diverse sample, allowing researchers to capture a broad range of perspectives, enhance reliability, and facilitate comparisons across different demographic groups. Additionally, closed-ended Likert-scale questions provide quantifiable data that can be analyzed statistically, yielding objective insights into complex phenomena. The anonymity they offer can encourage participants to respond more honestly, especially on sensitive issues such as their attitudes.

Table 1 delineates the demographics of the participating teachers. From May to November 2023, researchers gathered data from 203 in-service teachers teaching chemistry, biology, physics, and integrated (or natural) science at various educational levels. This sample demonstrates a broad and diverse representation across Vietnam, including gender, academic qualifications, teaching experience, school levels, and prior exposure to ISE.

A strong majority of participants were female (76.4%), reflecting the gender distribution of more female instructors, which is common in the teaching profession in Vietnam. Most teachers held bachelor's degrees, with a smaller proportion holding postgraduate qualifications, suggesting a range of academic preparation. Teaching experience was well distributed, with roughly one-third in their early career (less than 5 years), another third in the mid-range (5–10 years), and nearly 40% bringing more than a decade of experience, allowing insights from multiple career stages. In terms of teaching context, participants represented elementary, secondary, and high schools, as well as inter-level institutions, ensuring perspectives from across the education system. Notably, over one-third of the teachers had completed ISE training, making the sample particularly relevant for capturing both novice and trained viewpoints. Taken together, these characteristics suggest that the sample offers a meaningful and reasonably representative cross-section of Vietnamese science teachers, strengthening the reliability of the study's findings for informing educational reform.

Baseline characteristics	Full sample	Full sample
	n	%
Gender		
Male	48	23.6
Female	155	76.4
Teaching experience		
< 5 years	68	33.5
5-10 years	57	28.1
> 10 years	78	38.4
Professional development		
Not participating	69	34.0
Participated but not yet proficient	75	36.9
Participated and proficient	59	29.1
Education level		
Undergraduate degree	157	77.3
Postgraduate degree	46	22.7
School level		
Primary school	41	20.2
Secondary school	94	46.3
High school	43	21.2
Inter-level secondary school & high school	25	12.3

Table 1: the Distribution of Teachers by Gender, Educational Background, Teaching Experience, and Educational Level

The Instrument

The cross-sectional questionnaire in this study was adapted from the validated DAS instrument of van Aalderen-Smeets and Walma van der Molen (2013) and the aforementioned framework of primary teachers' attitudes toward science developed by van Aalderen-Smeets et al. (2012). Thus, the final instrument included 24 items of three dimensions as the cited theoretical framework of Figure 1 respectively, including (1) the cognitive beliefs: the relevance and importance of ISE (R) and perceived difficulty (D), and (2) the affective state including anxiety (A), and (3) perceived control including self-efficacy (S) and perceived dependence on contextual factors (C). Participating teachers were asked to respond to a five-point scale of attitudes toward teaching integrated science, ranging from "strongly disagree" to "strongly agree".

The changes and improvements made to the questionnaire language also took into account the four important aspects of teaching ISE (Åström, 2008): Combining different scientific

fields, making the material relevant to everyday life, using student-centered teaching methods, and showing how science works. Therefore, the original instrument, DAS, underwent several modifications, necessitating validation and reliability testing of the final questionnaire. Initially, we conducted a content and face validity analysis. Three invited experts in science education expressed their approval and provided feedback on the translation process and the terminology used in the Vietnamese context. Secondly, we determined the Kaiser–Mayer–Olkin (KMO) and Bartlett's test of sphericity to verify the adequacy of the sample. The KMO test score was .884, showing that the factor analysis is appropriate. Bartlett's test of sphericity is statistically significant ($p < .001$), indicating that the observed variables are correlated within the factor. Finally, we evaluated the reliability of each dimension using Cronbach's alpha coefficient. All calculated alphas ranged from .829 to .935, indicating highly reliable scales (Nunnally, 1978).

Next, we conducted a confirmatory factor analysis (CFA) to assess the factor validity. According to Hu and Bentler (1999), the results indicate good fit when the CMIN/df value is less than 3, the RMSEA is less than 0.08, the CFI is greater than 0.9, and the TLI is greater than 0.9. Table 2's validation work established the developed instrument as a well-validated tool.

# of items	Cronbach's alpha	Construct validity			
		CMIN/DF	RMSEA	CFI	TLI
24	.887	2.270	0.079	.926	0.915

Table 2: Cronbach's Alpha Reliability and Construct Validity for Each Subscale of the Questionnaire.

Data analysis

This study employed AMOS 20 and SPSS 26 for quantitative analysis. For instrument development, Cronbach's alpha coefficients were calculated to assess the reliability of the research model. For validation work, the KMO value and Bartlett's test of sphericity were initially calculated to verify the sampling adequacy. CFA was used to test the appropriateness of the initially declared factor structure using model fit indices.

The first research question was answered by utilizing descriptive statistical analysis. The second one was addressed by evaluating the differences between subgroups. A one-way ANOVA was used to compare attitudinal scores across subgroups. Tukey's honestly significant difference test was calculated for post hoc comparisons. The eta-squared values were also calculated to examine the effect size of differences. Cohen (2013) classified eta-squared values based on the benchmark of small (0.01), medium (0.06), or large (0.14) effect.

RESULTS

RQ1. What are Vietnamese science teachers' attitudes toward teaching integrated science?

The mean of each dimension was examined to evaluate the overall teacher attitude toward integrated science teaching. Specifically, the mean values of *Perceived relevance* (*R*), *Perceived difficulty* (*D*), *Anxiety* (*A*), *Self-efficacy* (*S*), and *Context dependency* (*C*) are 3.89 (*SD* = 0.97), 3.25 (*SD* = 1.04), 2.96 (*SD* = 1.06), 3.41 (*SD* = 0.95), and 3.95 (*SD* = 0.90) respectively. Their distributions were illustrated in the following box plots (see Figure 2).

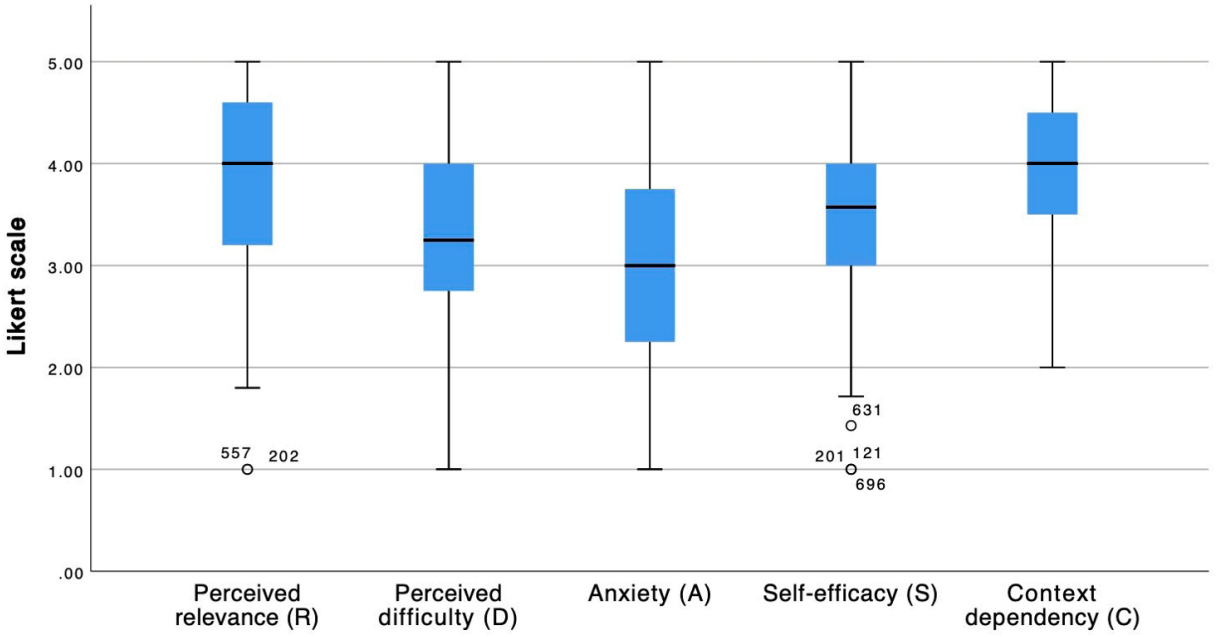

Figure 2: Box and Whisker Plots of Distributions of Five Factors: Anxiety (*A*), Context Dependency (*C*), Perceived Difficulty (*D*), Perceived Relevance (*R*), Self-efficacy (*S*)

Regarding cognitive beliefs, *Perceived relevance* (*R*) showed a first quartile (*Q1*) of about 3.25. In other words, over 75% of participating teachers acknowledged the critical role of ISE in enhancing students' lives and learning outcomes, as well as positively contributing to their professional development. Participants specifically highlighted their belief that "ISE is essential for making students more involved in technological and socio-scientific problems in society", and that "inexperienced teachers should receive preparation training on ISE". This underscores the high value teachers place on ISE for shaping student engagement and their own career trajectories. For the perceived *difficulty* dimension (*D)*, *Q2* (median) is about 3.30, indicating that nearly half of the participants found integrated science pedagogy challenging. Despite recognizing its value, they noted several specific difficulties that hindered their implementation of ISE, with participants underscoring challenges such as finding topics "complicated," struggling to "employ learner-centered teaching methods," and encountering difficulty "to design and implement scientific inquiry practices in my science class."

Anxiety is a significant affective component of attitudes and attitudinal theories because it directly influences an individual's emotional response to a particular object, situation, or behavior, shaping how attitudes are formed and expressed. Given the remarkable level of perceived difficulty, it is reasonable that the lowest mean was the *anxiety* dimension (*A*). Its median of 3.00 indicated that 50% of participants acknowledged experiencing stress during ISE implementation. This finding suggests that despite its adoption, many teachers approach integrated science with a sense of emotional discomfort, reflecting the significant role anxiety plays in shaping their attitudes toward ISE.

Despite the specific difficulties encountered during ISE implementation, participants reported a high level of *self-efficacy* (*S*), one of the perceived control aspects, with 75% of participants expressing a strong belief in their capability to perform ISE (*Q1* = 3.00). This finding is particularly notable given that only one-third of the total had received formal professional development to be certified. They showed high confidence in their ability to "integrate disciplines and/or technology contents" and "deal with questions about integrated science from students".

Lastly, the highest-scoring factor was *contextual dependency* (*C*), which highlights how external factors and situational constraints critically shape a teacher's attitude toward implementing ISE. Our findings show that over 75% of participants strongly agree that these contextual factors are highly influential. They emphasized the importance of access to resources, such as information and teaching materials, as well as support from colleagues and the school. This suggests that a lack of resources and support is a major barrier, and providing these elements may be the single most decisive factor for successful ISE implementation.

However, consistently high standard deviations reflect limited participant consensus. This variability, potentially driven by demographic diversity, justifies the examination of individual factors undertaken in RQ2.

RQ2: What contextual factors shape Vietnamese science teachers' attitudes toward teaching integrated science?

RQ2 was addressed using one-way ANOVA (see Table 3 and Table 4) and post hoc comparisons (see Table 5). Prior to conducting the one-way ANOVA, the underlying statistical assumptions were carefully assessed. The normality of the samples was examined, and the results confirmed that the distributions did not deviate significantly from normality. In addition, the assumption of homogeneity of variances was tested and found to be satisfied, indicating that variances across the groups were equivalent. Taken together, these results confirmed that the assumptions for conducting a one-way ANOVA were fulfilled.

Overall, teachers' attitudes towards integrated science teaching were largely consistent across subsamples, except for the professional development and school-level groups. There were no significant differences in attitudinal scores between male and female teachers. Similar trends were observed for teaching experience and educational level backgrounds (see Table 4).

On the other hand, participations in professional development (PD) indicated statistically significant difference among three subgroups at the $p < .05$ level in three dimensions: perceived difficulty (*D*: $F = 4.129$, $p = .017$), anxiety (*A*: $F = 3.676$, $p = .027$), self-efficacy (*S*: $F = 14.025$, $p < .001$).

For perceived difficulty, a significant difference was observed between teachers who participated in PD and demonstrated proficiency in ISE knowledge or execution competence ($M = 3.00$, $SD = 1.11$) and those who did not participate in PD ($M = 3.45$, $SD = 0.95$). Teachers who participated in PD but exhibited lower ISE knowledge proficiency or execution competence scored the highest in the anxiety dimension ($M = 3.13$, $SD = 0.98$), indicating greater anxiety compared to the other groups, particularly those with high proficiency. Regarding self-efficacy, post hoc comparisons in Table 5 revealed that teachers who participated in training and demonstrated ISE proficiency ($M = 3.85$, $SD = 0.75$) had significantly higher self-efficacy scores than those who attended training but achieved lower proficiency ($M = 3.28$, $SD = 0.94$) or those who had not participated in training at all ($M = 3.18$, $SD = 0.99$). These results, summarized in Table 3, suggest that teachers who received sufficient training and attained high ISE proficiency generally exhibited more positive attitudes toward integrated science teaching, whereas those with less training or proficiency experienced heightened anxiety and perceived greater difficulty.

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Variable	*n*	The relevance and importance (*R*)		The perceived difficulty (*D*)		Anxiety (*A*)		Self-efficacy (*S*)		Perceived dependence on context factor (*C*)	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
	203	3.89	0.97	3.25	1.04	2.96	1.06	3.41	0.95	3.95	0.90
Gender											
Male	48	3.86	0.96	3.19	1.01	2.94	1.03	3.45	0.93	3.92	0.89
Female	155	3.97	1.02	3.45	1.10	3.01	1.16	3.31	1.01	4.04	0.92
Teaching Experience											
< 5 years	68	4.05	0.88	3.28	1.08	2.90	1.07	3.45	0.88	4.01	0.88
5-10 years	57	3.89	0.93	3.37	0.90	3.06	1.01	3.55	0.86	3.97	0.83
> 10 years	78	3.74	1.06	3.14	1.09	2.93	1.10	3.29	1.06	3.88	0.97
Professional Development											
Not participating	69	3.80	1.06	3.45	0.95	3.00	1.11	3.18	0.99	3.99	0.89
Participated but not yet proficient	75	3.84	0.99	3.27	1.03	3.13	0.98	3.28	0.94	3.88	0.93
Participated and proficient	59	4.04	0.82	3.00	1.11	2.69	1.06	3.85	0.75	3.99	0.88
Education Level											
Undergraduate degree	157	3.88	1.02	3.20	1.08	2.94	1.07	3.42	0.99	3.94	0.93
Postgraduate degree	46	3.92	0.80	3.45	0.87	3.02	1.04	3.39	0.79	3.98	0.79
School Level											
Primary school	41	4.06	0.86	3.13	1.04	2.89	0.95	3.36	1.00	3.88	0.96
Secondary school	94	3.71	1.04	3.12	1.08	3.01	1.08	3.40	0.98	3.91	0.94
High school	43	3.97	0.93	3.45	0.95	2.94	1.09	3.41	0.84	3.93	0.84
Inter-level Secondary school & High school	25	4.10	0.88	3.63	0.86	2.90	1.13	3.55	0.96	4.26	0.67

Table 3: Teachers' Attitudes Based on Gender, Educational Background, Teaching Experience, and Educational Institution.

Variable	Gender		Teaching experience		Professional development		Education level		School level	
	$F(p)$	η^2	$F(p)$	η^2	$F(p)$	η^2	$F(p)$	η^2	$F(p)$	η^2
Perceived relevance (*R*)	0.609 (.436)	.126	2.548 (.081)	.098	1.476 (.231)	.090	.100 (.752)	.102	2.557 (.056)	.172
Perceived difficulty (*D*)	3.018 (.084)	.085	1.049 (.352)	.087	4.129 (.017)	.112	2.642 (.106)	.065	3.066 (.029)	.076
Anxiety (*A*)	.199 (.656)	.088	.452 (.637)	.055	3.676 (.027)	.077	.232 (.630)	.066	.202 (.895)	.078
Self-efficacy (*S*)	1.040 (.309)	.138	1.833 (.163)	.091	14.025 (.000)	.200	.043 (.835)	.131	.300 (.826)	.123
Context dependence (*C*)	.857 (.356)	.060	.562 (.571)	.097	.540 (.584)	.068	.083 (.773)	.091	1.735 (.161)	.073

Note: Values in bold indicate significance at the p < .05 level.

Table 4: Differences between Groups in terms of Overall Teachers' Attitudes toward Integrated Science

Background characteristics		Perceived relevance (R)		Perceived difficulty (D)		Anxiety (A)		Self-efficacy (S)		Context dependence (C)	
(*I*)	(*J*)	(*I-J*)	SE	(*I-J*)	SE	(*I-J*)	SE	(*I-J*)	SE	(*I-J*)	SE
Professional Development	**Professional Development**										
Not participating	Participated but not yet proficient	-.04	0.142	0.18	0.151	-0.14	0.156	-0.10	0.127	0.11	0.123
Not participating	Participated and proficient	-.24	0.151	**0.45**	**0.161**	0.31	0.166	**-0.66**	**0.135**	0.01	0.130
Participated but not yet proficient	Participated and proficient	-.20	0.148	0.27	0.158	**0.45**	**0.163**	**-0.56**	**0.132**	-0.10	0.128
School Level	**School Level**										
Primary school	Secondary school	.35	.158	.01	.170	-0.12	.179	-0.05	.152	-0.02	.137
Primary school	High school	.09	.184	-.32	.198	-0.05	.208	-0.05	.177	-0.05	.159
Primary school	Inter-level secondary school & high school	-.03	.214	-.50	.230	-0.01	.242	-0.19	.205	-0.38	.185
Secondary school	High school	-.26	.155	-.33	.167	0.07	.176	0.00	.149	-0.02	.134
Secondary school	Inter-level secondary school & high school	-.38	.190	-.51	.204	0.11	.215	-0.14	.182	-0.35	.164
High school	Inter-level secondary school & high school	-.12	0.212	-0.18	0.228	0.04	0.240	-0.14	0.204	-0.33	0.184

Note: Values in bold indicate significance at p < .05 level. (I-J) = Mean Difference, SE = Standard Error

Table 5: Post hoc Comparisons in Overall Teachers' Attitudes toward Integrated Science

Besides, teachers from different school levels also showed a significant difference at the < .05 level in their *perceived difficulty* of integrated science (*D*: $F = 3.066$, $p = .029$). However, no clear evidence of specific differences between pairs of school-level subgroups emerged, and the mean scores presented in Table 3 already illustrate the observed variations.

DISCUSSION

Our study adopted the constructs of attitudes from Thibaut et al. (2018, 2019) to examine teachers' attitudes towards ISE and the contextual factors related to these attitudes. From the perspective of educational and scientific efficiency, ISE offers a way to organize STEM learning that reduces fragmentation across disciplines and promotes the transfer of concepts and skills across subject boundaries. Our examination of attitudes toward integrated science directly engages with questions of educational efficiency, since insight into teachers' and learners' perceptions of integrated STEM is a necessary foundation for developing instructional models that make optimal use of time, resources, and content.

Our findings indicate that Vietnamese teachers generally show favorable attitudes toward the new general curriculum, appreciating its relevance and significance for human capital development, job prospects, and everyday life, as also noted by a recent study by Pham et al. (2023). Specifically, teacher participants demonstrated significant self-efficacy regarding ISE, believing strongly in its relevance and importance for future skills, as it covers inquiry-based, active, and real-world learning. Our finding warrants further exploration, as it starkly contrasts with the results of Vu (2021) and Thuan and Mau (2021), which highlighted deficiencies in

integrated science knowledge among Vietnamese teachers in real-world practice and implicitly suggested that their beliefs and self-efficacy may be illusory.

Despite teachers' highly positive attitudes toward their perceived relevance and self-efficacy, a cautious interpretation is warranted given reported anxiety and implementation difficulties. While anxiety scores were moderate, nearly half of the participants maintained that they had dealt with pedagogical and emotional challenges in pragmatic teaching. Consequently, policymakers and professional development trainers are reminded to closely monitor the current and future changes in teaching attitudes toward ISE. One potential recommendation is to focus on educators' emotional states alongside collegial support (Ualesi and Ward, 2018) or to promote the implementation of ISE by incorporating inquiry-based techniques and a student-centered methodology through increased modeling and scaffolding via teacher-practitioner inquiry shadowing. Teacher-practitioner inquiry shadowing entails a reflective, systematic approach among ISE experts and in-service teachers, in which teachers are guided to examine their own practices to improve teaching efficacy, address classroom challenges, and deepen their educational knowledge (Dinh and Nguyen, 2023).

As for the governmental level of support, supplying educators with contextually relevant educational resources, such as experienced teacher-generated lesson templates or culturally tailored pedagogical strategies for Vietnamese lesson planning, including textbooks and research-based or theoretical references, presents a promising avenue for experimentation more than co-teaching (Dinh, 2023; Nguyen et al., 2020). Other options to explore include integrated science textbooks (Winarno, 2020) and hands-on science teaching kits or equipment, since most available textbooks are collections of individual chapters from specialized subjects rather than demonstrating integration (Nguyen et al., 2020).

Regarding RQ2, our findings clarify the relationship between teacher attitudes and contextual factors. This study enriches the existing literature by providing critical empirical evidence specifically within the context of a developing country. Specifically, this study found contrastive findings with other studies cited above (e.g., Al Salami et al., 2017; Margot and Kettler, 2019). Herein, there was no statistically significant difference in teachers' attitudes toward ISE based on their gender, years of teaching experience, or educational level. Recently, Pillai et al. (2022) found a significant relationship between teacher demographics (gender, years of experience, and training) and attitudes toward educational reform in Vietnam. However, our findings contradict this, as our participants' attitudes toward ISE showed no such associations. This disparity suggests that the increased complexity of ISE, involving substantial changes in content knowledge (conceptual structure), pedagogical skills, and teaching resources, may attenuate the effects of demographic variables. Our findings also contradict those of Thi To Khuyen et al. (2020), who reported that science teachers' views on integrated STEM education varied by educational background, yet our findings and theirs are consistent in that there were no differences in perceived difficulties across groups with different teaching experience.

Indeed, our research findings indicate that high-quality *professional development* (PD), which leads to greater knowledge retention and execution competence among attendees, is *a major factor* in alleviating science *teachers' perceived difficulty*, *anxiety*, and *reduced self-efficacy*. In other words, teachers who have been trained yet display low proficiency and execution competence after the training are most likely to experience heightened anxiety when teaching integrated science. Most importantly, this finding corresponds with several cited studies above that teachers' attitudes, especially their affective states, must be considered prior to any PD in ISE (cf. Aldahmash et al., 2019; Dinh and Nguyen, 2023; Thibaut et al., 2019; Thi To Khuyen et al., 2020; van Aalderen-Smeets and Walma van der Molen, 2015). Specifically, our finding echoed the emphasis of Ualesi and Ward (2018) and Thibaut et al. (2018) on the necessity of ensuring consistent and thorough PD; they highlighted that the quality of PD must include management support, peer collaboration, and structured guidance to effectively transition from traditional didactic teaching to a reformed, student-centered teaching style.

Additionally, our findings are also significant because, despite the existence of various teacher education or training programs (Nguyen and Pham, 2021; Nguyen et al., 2020), the low efficiency of ISE implementation can be attributed to the fact that the knowledge retention and execution competence of the participating teachers have not been adequately monitored and evaluated. To assess teachers' knowledge retention and competence, the following abilities may be evaluated via peer observation or teachers' annual assessment: the capacity to implement integrated science knowledge, the ability to connect lessons to students' everyday problem-solving scenarios, the pedagogical skill in delivering knowledge through a student-centered teaching approach rather than traditional lecturing, and the skill to design activities that adhere to a scientific inquiry-based framework, facilitating students' application of knowledge to real-world contexts.

Third, although there was no clear evidence of specific differences between pairs of school-level subgroups, the mean scores for perceived difficulties in ISE showed some variation, especially among secondary school teachers. As Weinberg and Sample McMeeking (2017) pointed out, secondary school teachers see themselves as experts in their own content; yet, they frequently regard themselves as lacking proficiency in other fields and feel deprived of appropriate and supportive curriculum materials. In Vietnam, secondary teachers face additional problems during the transition to integrated science, as the traditional national curriculum historically fragmented science into distinct subjects upon leaving elementary school. Currently, this divide tends to be eradicated, leading instructors to feel that ISE is perplexed and to perceive ISE preparation as increasingly daunting. Therefore, our findings call for further exploration in future research, as they may still indicate the need for targeted professional development or resources tailored to address their specific challenges and perceptions at different school levels. Professional development should also be applied

consistently across school levels; if district and school leaders ensure that science teachers attain competence in ISE through frequent training, disparities in ISE implementation across different school levels can be mitigated (Nguyen et al., 2020; Whitworth and Chiu, 2015).

Finally, a deeper analysis of the link between the teachers' claimed self-efficacy and their actual classroom practices is also limited. While the questionnaire-based methodology was effective for identifying broad attitudinal trends, it was insufficient to demonstrate how self-reported confidence translates into observable instructional behaviors. Moreover, the cross-sectional design and the restricted sample of in-service Vietnamese teachers constrain the generalizability of the findings beyond this context and prevent causal inferences about changes in attitudes over time. More research can help fill this methodological gap by considering mixed-methods designs or by widening the target populations of teachers.

CONCLUSION

While Integrated Science Education (ISE) is proven to enhance student outcomes, developing countries such as Vietnam face substantial implementation hurdles. The persistence of traditional, single-discipline curricula has resulted in a lack of pedagogical strategies necessary to sustain ISE in K-12 schools. This quantitative research, therefore, investigates the attitudes of science teachers with different demographic backgrounds towards ISE, within the context of a top-down educational reform implemented by the Ministry of Education, a centralized national educational leadership. Our findings thus are significant because they highlight that the limited efficiency of ISE implementation in Vietnam is associated with both the availability of teacher training programs and the lack of systematic monitoring and evaluation of teachers' knowledge and execution competence. Moreover, understanding science teachers' perspectives on the transition from specialization to ISE through a contextualized lens offers indispensable insights into the specific challenges and opportunities for integration, enabling targeted, impactful interventions from the school level to statewide or national policymaking. Unlike previous studies, the contextual factors, such as gender, teaching experience, and educational levels, do not matter. Rather, in a developing country setting, the quality of professional development and, to some degree, school levels are crucial contextual factors associated with teachers' attitudes towards transformative ISE, addressing public concerns around the integration method in educational reform.

Consequently, a critical lesson for advancing ISE is that priority must be given to high-quality professional development tailored to specific school levels and aligned with systemic reforms. Future research should focus on designing and validating these targeted professional development initiatives to address the urgent, distinct challenges facing teachers.

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