Research Article

CASE STUDY OF THE IMPLEMENTATION OF INTEGRATED SCIENCE PROCESS SKILLS IN CHEMISTRY TEACHING

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ABSTRACT

The purpose of this mixed method case study is to explore the level of implementation of Integrated Science Process Skills (ISPS) into Chemistry teaching among secondary school teachers in selected districts in Malaysia. Seven chemistry teachers were involved in the study; The quantitative findings showed a high level of overall execution (M = 4.45, SD = 0.45), with the control variables and interpreting the data recording the highest mean score (M = 4.57). The operationally construct, while still high, has the lowest average score (M = 4.26). Qualitative analysis shows that teachers generally guide students in formulating hypotheses, emphasize identifying and discussing variables, require students to explain and define terms operationally, provide students support in data interpretation, and ensure students are familiar with experimental procedures and materials. Overall, the findings show a strong integration of ISPS in chemistry lessons, with specific constructions receiving varying levels of emphasis. These results underscore the need for ongoing support and targeted professional development to ensure balanced implementation across all components of the ISPS, thus enhancing students' high-level thinking and scientific research skills.

Keywords: Integrated Science Process Skills, chemistry education, implementation level, mixed-methods

INTRODUCTION

According to Turiman et. al (2012), scientific literacy among students relies on the conceptual understanding as well as their possession of Science Process Skills (SPS), vital for conducting structured inquiries, scientifically solving emergent issues and making evidence-based arguments across contexts. In the Malaysian Secondary School (KSSM) Standard Curriculum, SPS is systematically integrated into the science and chemistry curriculum to prepare students in 21st century learning competencies (Ministry of Education Malaysia, 2016).

There are two main categories of SPS. Basic Science Process Skills (BSPS)—typically introduced during primary school—include observing, classifying, measuring, and using numbers, inferring, predicting, communicating, and using spatial-temporal reasoning. Integrated Science Process (ISPS) skills, introduced at the secondary level, require more advanced cognitive involvement and include data interpretation, defining operations,

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controlling variables, formulating hypotheses, and experimenting (Mohd Al-Junaidi & Ong, 2012; Turiman et al., 2012).

ISPS is important to connect theory and practice in chemistry education. These skills enable students to create controlled experiments, modify and control variables, assess and interpret data, and draw accurate scientific conclusions (Kamarudin et al., 2022). Along with enhancing HOTS, ISPS builds problem-solving and scientific reasoning skills, readying students for complex challenges (Norazilawati et al., 2016).

Nevertheless, despite its significance, ISPS isn't always used in classrooms, according to research. Their effective integration is often hampered by obstacles like poor labs, large classes, and too much exam focus (Kamarudin et al., 2022; Tuan et al., 2005). In addition, the varying incorporation of these skills in teaching and learning activities results from variances in teachers' professional training, pedagogical experience, and familiarity with ISPS (Norazilawati et al., 2016).

Because of these difficulties, the real-world use of ISPS in chemistry classes needs to be studied. By understanding current practices, we can improve training, use resources, and teach. To address this gap, this study investigated chemistry teachers' ISPS implementation in Malaysia, focusing on self-reported teaching and integration strategies.

LITERATURE REVIEW

Integrated Science Process Skills (ISPS) is a high-level competency that synthesizes a variety of Basic Science Process Skills (BSPS) to enable students to conduct legitimate scientific investigations and use logical reasoning effectively. The Malaysian chemistry curriculum's ISPS includes five core skills: data interpretation, operational definition, variable control, hypothesis formulation, and experimentation (Mohd Al-Junaidi & Ong, 2012).

This ability is crucial in chemistry teaching, as it bridges macroscopic observations, submicroscopic explanations, and symbolic representations, per Johnstone's "Chemical Triangle." If properly implemented, ISPS enables students to create and execute controlled experiments, properly change variables, correctly analyze results, and validate findings with data.

Incorporating ISPS into chemistry education promotes active learning, critical thinking, and problem-solving skills. Students can design valid experiments with ISPS when they're taught it explicitly and consistently, and also test hypotheses and make evidence-based conclusions (Norazilawati et al., 2016).

Furthermore, ISPS fosters Higher Order Thinking Skills (HOTS), aligning with Malaysia's Education Ministry's aim to equip students for 21st-century cognitive and practical needs (Ministry of Education Malaysia, 2016). These skills also help students apply science principles beyond school, making learning more relevant, engaging, and transferable (Turiman et al., 2012).

In Malaysia, ISPS integration differs based on the subject, school environment, and teacher preparedness, as research indicates. Research shows that science lessons don't always consistently use ISPS (Mustafa, 2021; Norazilawati et al., 2016). Lab sessions frequently emphasize ISPs more than theory lessons, which restricts students' chances to use these skills in diverse settings (Kamarudin et al., 2022).

According to Norazilawati et al. (2016), ISPS components like controlling variables are used less than skills like interpreting data. This difference implies that though teachers know ISPS matters, difficulties like time constraints, syllabus expectations, and resource shortages influence how often they use it.

Similar challenges have been documented internationally. For example, Feyzioğlu (2009) reports that in many developing countries, the implementation of ISPS is hampered by exam-driven curriculum, inadequate teacher training, and inadequate inquiry-based learning programs.

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Though prior studies considered ISPS in Malaysia, a few concentrated on chemistry education. The specific focus of this subject is important given the chemical reliance on experimental validation to reinforce theoretical concepts.

This study addressed this gap by assessing the level of self-reported ISPS implementation among chemistry teachers in selected Malaysian districts. This study's findings should guide professional development, resource allocation, and curriculum improvements.

METHODOLOGY

Research Design

The study employed a case study design to examine ISPS implementation in chemistry. A case study approach has been chosen to allow for an in-depth exploration of teachers' actual practices and experiences in the context of their authentic teaching. Researchers widely use this design in education to provide descriptive and contextual insights into classroom practice (Cohen et al., 2018; Yin, 2018).

Past science education case studies have used mixed methods, such as surveys and interviews, to show skill implementation levels and difficulties (Norazilawati et al., 2016; Mustafa, 2021).

Participants

The study involved seven chemistry teachers from secondary schools located in selected Malaysian districts. These educators were chosen from 23 chemistry teachers in the district. Their selection utilized facility sampling, considering ease of access and willingness to engage (Etikan et al., 2016).

Eligibility criteria include:

(a) Currently teaching chemistry at the upper secondary level under the *Kurikulum Standard Sekolah Menengah* (KSSM).
(b) Having at least one year of chemistry teaching experience.

The sample represents a wide range of teaching experiences, academic qualifications, and school settings, thus offering a broad perspective on the level of implementation of ISPS in chemistry classrooms (Table 1).

Table 1

Demographics of respondents

Demography	Item	Frequency	Percentage (%)
Gender	Men	0	0
	Woman	7	100.0
Nation	Malay	6	85.7
	China	1	14.3
	India	0	0
Age	Under 20 years old	0	0.0
	21-30 years old	1	14.3
	31-40 years old	4	56.1
	41-50 years old	2	28.6
	51-60 years old	0	0.0

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Academic Graduation	Diploma	0	0.0
	Bachelor	7	100.0
	Master's Degree	0	0.0
	PhD	0	0.0
Eligibility overview	Teaching Certificate	0	0.0
	Diploma in Education	1	14.3
	Bachelor of Education	6	85.7
	Guru Sandaran	0	0.0

Instruments

Two instruments were used:

Quantitative Instruments – Structured Questionnaire

The quantitative instrument used was a structured questionnaire designed to investigate the implementation of ISPS among chemistry teachers. The instrument consists of two parts:

1. Part A: Respondent demographic factors.
2. Part B: 25 items that measure ISPS implementation, divided into five constructs
3. interpreting data, defining operations, controlling variables, formulating hypotheses, and experimenting (Table 2).

All items in Section B used a five-point Likert scale: 1 = *Never*, 2 = *Rarely*, 3 = *Sometimes*, 4 = *Often*, 5 = *Always*.

Table 2

Distribution of questionnaire items

Construct	Items ID	Number of Items
Formulating hypothesis	1, 2, 3, 4, 5	5
Controlling variables	6, 7, 8, 9, 10	5
Define operationally	11, 12, 13, 14, 15	5
Interpreting data	16, 17, 18, 19, 20	5
Experimenting	21, 22, 23, 24, 25	5

Qualitative Instruments – Semi-Structured Interviews

The qualitative instrument is a semi-structured interview conducted with several teachers randomly selected from a sample. The interview protocol is designed to further explore and elaborate on the findings of the questionnaire. It consists of semi-open-ended questions that are in line with the five constructions of ISPS and adapted from Saniah Sembak (2017).

The interview aims to provide a more in-depth view of how teachers implement ISPS in their lessons. Answers are open and flexible, allowing participants to elaborate independently, and follow-up questions are allowed for clarification. Table 3 shows the distribution of semi-structured interview items.

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Table 3

Distribution of semi-structured interview items

Construct	Items ID	Number of Items
Formulating hypothesis	3, 4, 5, 6	4
Controlling variables	7, 8, 9, 10	4
Define operationally	11, 12, 13, 14	4
Interpreting data	15, 16, 17, 18	4
Experimenting	19, 20, 21, 22	4

Validity

In this study, the validity of the instrument was established through the method of percentage agreement, which involves evaluation by two validating experts in chemistry education.

Validity of the Quantitative Instrument

The instrument's validity was confirmed in this study by two chemistry education experts, using percentage agreement.

The initial phase saw the development of 50 questionnaire items, covering the five Integrated Science Process Skills (ISPS) constructs: interpreting data, defining operations, controlling variables, formulating hypotheses, and experimenting. After expert review, 25 items were taken out because they were repetitive or semantically similar, leaving 25 items in the questionnaire (Table 4).

Content validity coefficients above 70% are generally considered acceptable for educational research instruments (Lawshe, 1975; Zamanzadeh et al., 2015). In this study, expert agreement exceeded this threshold, indicating that the instrument had a satisfactory content validity to evaluate the implementation of ISPS among chemistry teachers (Table 5).

Table 4

Distribution of questionnaire items after expert verification

Construct	Number of Items	Number of Dropped Items
Formulating hypothesis	10	5
Controlling variables	10	5
Define operationally	10	5
Interpreting data	10	5
Experimenting	10	5
Number of items	**50**	**25**

Table 5

The percentage agreement for 25 items

Experts	Expert Score	Maximum Score	Percent Approval	Expert Views
1	92	100	92	Accepted
2	91	100	91	Accepted
Overall Average	**91.5**	**100**	**91.5**	**Accepted**

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Validity of the Qualitative Instrument

Qualitative validity refers to the extent to which the instrument adequately represents and addresses research objectives (Creswell & Poth, 2018; Morse, 2015). In this study, the validity of the qualitative instrument was evaluated by the same two expert validators who evaluated the quantitative instrument. Their assessment ensured that the semi-structured interview protocol was conceptually aligned with the study objectives, comprehensively encompassed all five constructs of the Integrated Science Process Skills (ISPS), and was contextually appropriate for the target participants.

Reliability

Reliability refers to the degree to which the instrument consistently produces stable and reproducible results across repeated applications (Tavakol & Dennick, 2011).

Reliability of the Quantitative Instrument

The quantitative instrument showed high reliability, with an overall Cronbach alpha coefficient of 0.882 for all 25 items (Table 6). The value surpasses the common 0.70 benchmark for educational research (Nunnally & Bernstein, 1994; Taber, 2018). Based on the findings, the instrument can reliably measure ISPS implementation levels due to its high internal consistency.

Table 6

Cronbach alpha *value* for the implementation of KPSB for chemistry teachers

Construct	Correlation of Items to Total Score	Alpha Value	Number of Items
Formulating hypothesis	0.707	0.685	5
Controlling variables	0.776	0.761	5
Define operationally	0.823	0.817	5
Interpreting data	0.669	0.670	5
Experimenting	0.763	0.745	5
Overall	**0.887**	**0.882**	**25**

Reliability of the Qualitative Instrument

The reliability of the qualitative instrument, i.e. a semi-structured interview protocol, has been established through an expert agreement with the appointed validator. In addition, the reliability was further supported by the pilot study, in which respondents demonstrated a clear understanding of the interview questions. This ensures that the protocol is not only conceptually valid but also can be interpreted consistently by participants, thereby increasing the reliability and reliability of the qualitative data collected.

Data Collection Procedure

The data collection procedure is illustrated in Figure 1. For the quantitative phase, researchers communicated with participants via email, WhatsApp, and Telegram. Data is collected online using Google Forms to ensure accessibility and convenience for respondents.

For the qualitative phase, the researcher conducted a semi-structured interview to gain an in-depth insight. This approach allows participants to elaborate on their experiences and practices related to the implementation of Integrated Science Process Skills (ISPS), while

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allowing researchers to investigate richer explanations and contextual information when necessary.

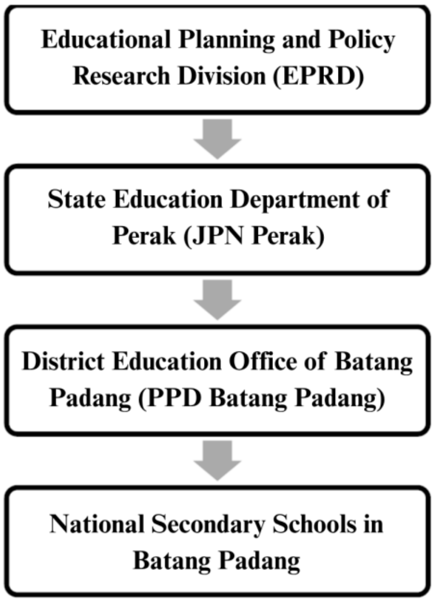

Figure 1 Data collection procedure

Data Analysis

For this study, the researchers will use descriptive statistics using *the Social Science Statistics Package (SPSS) Version 27* to analyse quantitative data to obtain frequency, percentage, mean and standard deviation. As for the qualitative data, the data was analysed from the transcription of interviews with three chemistry teachers which were analysed manually. After that, the researcher will begin to codify the transcription to recognize the patterns of themes associated with ISPS and analyze the data in a thematic analysis.

FINDINGS AND DISCUSSION

This mixed method case study integrates descriptive statistical analysis for quantitative data and thematic analysis for qualitative data to examine the level of implementation of Integrated Science Process Skills (ISPS) among chemistry teachers.

Quantitative Findings – Level of ISPS Implementation

Analysis of Table 7 shows that the overall level of implementation of Integrated Science Process Skills (ISPS) among chemistry teachers is high, with an average score of 4.45 (SD = 0.45). The average score for all five ISPS builds was above 4.20, showing consistently strong performance in each skill. Controlling and Interpretation data had the highest mean scores, both at 4.57 (SD = 0.48 and 0.50). These results highlight teachers' focus on identifying, manipulating, and controlling experimental variables and accurately interpreting and analyzing data.

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Table 7

Implementation level of Integrated Science Process Skills (ISPS) in chemistry lessons

Construct	Min	Standard Deviation	Indicator
Formulating hypothesis	4.46	0.66	High
Controlling variables	4.57	0.48	High
Define operationally	4.26	0.41	High
Interpreting data	4.57	0.50	High
Experimenting	4.37	0.37	High
Overall	**4.45**	**0.45**	**High**

The skill of formulating hypotheses achieved an average score of 4.46 (SD = 0.66), reflecting the teacher's strong involvement in encouraging students to develop testable scientific predictions. The trial recorded a mean score of 4.37 (SD = 0.37), indicating the frequent use of practical work and practical investigation in the lesson. The lowest mean score, although still categorized as high, was to Define operationally at 4.26 (SD = 0.41), indicating that this skill—requiring precise measurement articulation and definition of procedures—is slightly less emphasized than the other components of ISPS.

Quantitative Findings – Frequency and Percentage Scores

Analysis of Table 8 reveals that chemistry teachers show generally high levels of implementation across all five ISPS constructions.

Table 8

Frequency and percentage scores for the implementation of ISPS

No.	Item	Frequency (f) Percent (%)				
		1	2	3	4	5
	Formulating hypothesis					
B1.	I mention the word hypothesis when it comes to appropriate titles only	-	-	3 (42.9%)	3 (42.9%)	1 (14.3%)
B2.	I questioned the students about their knowledge of the hypothesis	-	-	2 (28.6%)	-	5 (71.4%)
B3.	I explain how to make a hypothesis to students	-	-	-	2 (14.3%)	5 (71.4%)
B4.	I guide students to form hypotheses using relevant variables	-	-	-	3 (42.9%)	4 (57.1%)
B5.	I guide students to form a statement that can be tested for veracity through practical activities	-	-	1 (14.3%)	3 (42.9%)	3 (42.9%)
	Controlling variables					
B6.	I ask students to list variables they know	-	-	-	3 (42.9%)	4 (57.1%)

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B7.	I discuss with students about the variables identified in the questions/ worksheets	-	-	-	2 (14.3%)	5 (71.4%)
B8.	I guide students to identify the variables involved in the activity/internship	-	-	-	2 (14.3%)	5 (71.4%)
B9.	I discuss the variables involved after the student conducts an activity/internship	-	-	2 (14.3%)	2 (14.3%)	4 (57.1%)
B10.	I explain what it means to define operationally to students	-	-	-	4 (57.1%)	3 (42.9%)
	Define operationally					
B11.	I ask students to explain a term using their own words	-	-	-	5 (71.4%)	2 (14.3%)
B12.	I guide students to explain terms that require them to make definitions operationally	-	-	1 (14.3%)	4 (57.1%)	2 (14.3%)
B13.	I ask students to make statements by attributing observations about changes during the activity/practice.	-	-	-	5 (71.4%)	2 (14.3%)
B14.	I guide students to make definitions operationally before carrying out activities/internships	-	-	1 (14.3%)	5 (71.4%)	1 (14.3%)
B15.	I ask students to make definitions operationally based on the questions/worksheets given	-	-	-	3 (42.9%)	4 (57.1%)
	Interpreting data					
B16.	I explain the meaning of the word data interpretation to students	-	-	-	6 (85.7%)	1 (14.3%)
B17.	I guide students to make interpretations from the data shown	-	-	-	5 (71.4%)	2 (14.3%)
B18.	I guide students to detect patterns/patterns on information in the form of tables, graphs or charts and answer questions/worksheets	-	-	-	4 (57.1%)	3 (42.9%)
B19.	I question the information presented by the students based on tables, graphs or charts	-	-	-	2 (14.3%)	5 (71.4%)
B20.	I guide students to formulate based on information from tables, graphs, or charts	-	-	-	5 (71.4%)	2 (14.3%)
	Experimenting					
B21.	I explain the procedure of an activity/internship before students do the activity/internship	-	-	1 (14.3%)	3 (42.9%)	3 (42.9%)

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B22.	I remind you about the precautions before students do activities/internships	-	-	-	2 (14.3%)	5 (71.4%)
B23.	I questioned and answered with students about the equipment in carrying out activities/internships	-	-	-	3 (42.9%)	4 (57.1%)
B24.	I question and answer students about the steps in carrying out activities/internships	-	-	-	2 (14.3%)	5 (71.4%)
B25.	I conduct a discussion on how to record/record observations correctly before the activity/internship	-	-	1 (14.3%)	1 (14.3%)	5 (71.4%)

continued

*1 (Never); 2 (Rare); 3 (sometimes); 4 (Frequent); 5 (very often).

For hypothesis construction, most teachers frequently or very frequently guide students in forming hypotheses, with 71.4% often explaining how to formulate hypotheses and 57.1% often assisting students in connecting relevant variables. Similarly, 71.4% of teachers often encourage students to express hypotheses, indicating a strong emphasis on hypothesis formulation during lessons.

In the construction of control variables, 71.4% of teachers often discuss the identified variables with students and guide them in recognizing the variables involved in the experiment. Furthermore, 57.1% frequently review variables after experiments, reflecting a consistent approach to strengthening variable control in practical work.

To define operationally, 71.4% of teachers often require students to explain terms in their own words and make operational definitions before conducting experiments. More than half (57.1%) guide students in determining variables operationally based on the worksheets or questions provided.

In interpretive data construction, the majority of teachers (71.4%) often guide students in making interpretations from data and in summarizing information from tables, graphs, or charts. However, 85.7% reported frequently having to explain data interpretation concepts before students could work independently, indicating that while practice is high, conceptual reinforcement remains important.

The experimental construct was also well executed, with 71.4% of teachers frequently reminding students of safety precautions and questioning them about experimental measures and apparatus. In addition, 71.4% of teachers often discuss the correct method of recording observations before practical work.

Qualitative Findings – Teachers' Perspectives

Thematic analysis of teacher interviews revealed that the implementation of Integrated Science Process Skills (ISPS) in chemistry lessons was influenced by a combination of pedagogical strategies, student readiness, and contextual constraints. Responses are categorized according to five ISPS constructs as shown in Table 9: formulating hypotheses, controlling variables, defining operations, interpreting data, and experimenting.

Table 9

Findings of teacher interviews based on five KPSB constructs

Construct	Interview findings
Formulating hypothesis	Two out of three teachers have given the same statement that they would encourage students to build hypotheses before

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	acting to help and guide them. Meanwhile, one of the three chemistry teachers stated that his students were able to build a hypothesis without help. However, sometimes he still helps in refining hypothetical sentences built by the students themselves.
Controlling variables	All three chemistry teachers interviewed stated that they would ask students to create variables based on their knowledge.
Define operationally	Every chemistry teacher who has been interviewed states they would insist that defining operationally is about what students do and what students see.
Interpreting data	Two out of three chemistry teachers interviewed faced the same problem, namely that students are often confused and unconfident in building graph axes. Therefore, they will guide their students to build a graph axis to ensure that all students successfully interpret the data. Meanwhile, one of the teachers stated that his students had no problems in building graphs. He also stated that he conducted a construct to interpret the data in terms of questioning and answering with students about the experimental findings.
Experimenting	All three chemistry teachers interviewed always emphasized experimental skills. They will make sure their students know every procedure and ingredients used in an experiment.

Teachers generally agree that formulating hypotheses is important in fostering students' scientific reasoning. Some participants mentioned that they often modeled how to formulate hypotheses that could be tested before allowing students to experiment independently. However, they noted that weaker students tend to struggle in connecting variables logically, causing teachers to provide more scaffolding through guided questions and examples.

Most teachers report that they explicitly teach variable concepts during practical work, using real-life examples to make the concepts relatable. They emphasize that students often confuse independent and dependent variables, requiring repeated reinforcement. Some teachers point out that due to time constraints, variable control is sometimes taught in theory rather than through direct investigation.

The teacher acknowledges that the definition of operation is often ignored unless specifically required by the experiment. Some participants admitted that students often gave definitions that were too general or lacked measurable elements. To address this, some teachers integrate operation-definition exercises into worksheets or pre-lab activities.

Many teachers report that data interpretation is a challenging skill for students, especially when graphs or charts are involved. Teachers observe that while students can often articulate trends, they struggle to explain the scientific reasoning behind them. This leads teachers to spend more time interpreting data and connecting it to theory.

Integrated Discussion

Analyzing quantitative and qualitative data gives us a complete understanding of ISPS use in chemistry teaching in the district. Teachers, in general, showed a high level of ISPS integration, focusing strongly on variables and data. This shows a deliberate attempt to help students design valid experiments, analyze results accurately, which is key to scientific research. However, the ability to define operations was a bit less strong, though still at a high level. The data indicates that some teachers struggle to define abstract scientific ideas in precise, measurable ways, perhaps because they lack effective strategies or don't prioritize this in their lessons.

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Subsequent qualitative findings revealed that ISPS was most often used during laboratory sessions and group activities, while theory-based lessons tended to remain content-heavy. Previous studies show a similar trend: practical use is valued more than developing conceptual skills. Challenges like time restrictions, exam-driven teaching, and insufficient lab resources still make consistent ISPS integration difficult in various teaching settings. Teachers also pointed out that their confidence in and training for ISPS pedagogy notably influenced skills integration, with those having more professional development demonstrating more balanced implementation.

The results imply that although ISPS implementation is of high quality, professional development is required to improve weaker elements, notably operational definitions, and to encourage ISPS integration in all courses. Filling this void will enhance students' higher-order thinking and problem-solving skills, supporting Malaysia's vision of scientifically literate citizens with 21st-century competence.

IMPLICATIONS AND CONCLUSIONS

This research explores ISPS implementation in Malaysian chemistry classes, using a mixed-methods case study. The study's findings reveal teachers effectively implemented ISPS, with a focus on controlling variables and interpreting data. These results reflect teachers' commitment to giving students key inquiry skills for designing valid experiments, analyzing data, and drawing conclusions based on evidence.

While the level of implementation is generally high, certain skills—especially defining operations—are comparatively underemphasized. Qualitative findings reveal that this may stem from limited teaching time, insufficient emphasis during lesson planning, and challenges in translating abstract concepts into measurable and observable terms. Additionally, ISPS integration was found to be more prevalent in lab-based lessons than in theory-focused sessions, reflecting a tendency to prioritize practical application over conceptual reinforcement.

In conclusion, while the high level of ISPS implementation observed in this study is commendable, continuous improvement requires strategic efforts to address the identified gaps. Such initiatives will contribute to producing scientifically literate students equipped with high-level thinking skills, in line with Malaysia's educational aspirations and the demands of 21st century learning.

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