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LABORATORY SAFETY KNOWLEDGE, ATTITUDES, PRACTICES, AND COMPLIANCE AMONG SECONDARY SCHOOL PRE-SERVICE SCIENCE TEACHERS: A PILOT STUDY

W. S. W. A. Yanee[1], N. N. Hamidi[1], A. Y. F. Khan*[1], C. Jianlei[1,2], H. M. Said[3], S. R. S. Aris[1]

[1]Faculty of Education, Universiti Teknologi MARA, Puncak Alam, Malaysia
[2]Department of Chemistry, Hengshui University, Hebei, China
[3]Sultan Hassanal Bolkiah Institute of Education (SHBIE), Universiti Brunei Darussalam, Bandar Seri Begawan, Brunei

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ABSTRACT

Effective laboratory safety is central to quality science education, yet limited evidence exists on Malaysian teachers' preparedness and adherence to safety standards. This pilot study aimed to validate an instrument measuring knowledge, attitudes, and practices (KAP) toward laboratory safety and to explore preliminary findings among pre-service secondary school science teachers. A cross-sectional pilot study was conducted with 30 pre-service teachers from Universiti Teknologi MARA (UiTM). Data was collected using a self-developed KAP questionnaire and a safety facilities checklist, both reviewed by experts for content validity. Item analysis was used for knowledge questions, while internal consistency was assessed using Cronbach's alpha for attitude and practice domains. Descriptive statistics summarised KAP levels and the availability and functionality of safety facilities. Knowledge items showed acceptable difficulty ($p = 0.50–0.80$) and discrimination ($D = 0.30–0.80$). Reliability was strong, with Cronbach's alpha values of 0.901 (attitude) and 0.905 (practice). Most respondents demonstrated high knowledge (70%) and universally positive attitudes (100%), yet practices were less consistent, with 23.3% reporting only moderate adherence. Laboratory facilities were largely available (87.5%), but functionality was low (32.7%), with deficiencies in safety data sheets (36.7%), chemical expiry records (40.0%), and first aid kits (56.7%). This pilot study highlights a disparity between pre-service teachers' knowledge and their actual laboratory practices, further constrained by poorly maintained safety facilities. The reporting of validity and reliability findings demonstrates that the instrument is robust and suitable for larger-scale investigations. Strengthening laboratory safety in schools requires targeted professional development, systematic facility maintenance, and consistent monitoring mechanisms.

Keywords: laboratory safety; pre-service science teachers; knowledge-attitude-practice (KAP)

INTRODUCTION

The development of a country is influenced by the performance of the students in science education (Taştan et al., 2018; Astawan et al., 2023). It is a key point in enhancing the quality of life as well as the environment (Charro, 2021; Maryanti et al., 2022). Beyond theoretical knowledge, science inspires curiosity and engagement through practical learning, with laboratory activities providing hands-on experiences that strengthen understanding and application of scientific concepts (Zengele & Alemayehu, 2016; Hamad Ameen & Ibrahim, 2022; Riaz et al., 2023; Da-

*Correspondence Address
E-mail: yuhainis@uitm.edu.my

myana, 2024). The use of laboratories is important, as science depends heavily on evidence derived mainly from experiments.

In Malaysia, laboratory-based learning begins as early as primary school to build familiarity with scientific concepts and procedures (Ministry of Education Malaysia, 2024). Duban et al. (2019), Akpullukcu and Cavas (2017), and Hill (2016) emphasised that teachers, as professionals, are expected to take reasonable steps to maintain lab safety. This includes bearing significant responsibility for implementing precautions and responding effectively to emergencies related to laboratory safety (Koç & Çavaş, 2022). Most importantly, they are responsible for ensuring that safety rules are consistently followed (Ali et al., 2018).

While beneficial for enhancing scientific literacy, laboratory activities also pose potential risks, especially for secondary school students who may have inadequate awareness of safety procedures (Caymaz, 2021). Students are more likely to encounter accidents in school laboratories compared to industrial settings due to their inexperience and the exploratory nature of their activities (Hensley et al., 2024). Various hazards in the lab can cause accidents (Walters et al., 2017; Kocak, 2019), and the accidents in laboratories may involve injury, illness, equipment damage, and lead to failure of the experiment (Ménard & Trant, 2020).

Hence, laboratory safety is needed to protect all individuals in the laboratory from accidents, injuries, and harm, thereby ensuring a safe working environment (Can et al., 2015; Koç & Çavaş, 2022; Hensley et al., 2024). In Malaysia, government agencies such as the Ministry of Education have made efforts by introducing the School Science Laboratory Management and Safety guidebook, textbooks, and science-based practical workbooks, which are implemented in secondary schools across Malaysia (Ali et al., 2018).

Despite efforts to enhance laboratory safety, reports of accidents continue in both global and local contexts, ranging from chemical burns in Nepal (Kandel et al., 2017), laboratory injuries in Sweden (Schenk et al., 2018), to mercury spills in Malaysia (Hassan et al., 2017), underscoring the importance of effective safety measures and supervision. Research indicates that many laboratory accidents stem from human factors (Ménard & Trant, 2020; Bai et al., 2022).

Laboratory safety is a pressing issue in science education, as science teachers are reported to have insufficient knowledge, attitudes, and practices (KAP) regarding laboratory safety. For instance, Hussein and Shifera (2022) reported only a moderate level of laboratory safety knowledge, and despite having moderate knowledge and a positive attitude, teachers' safety practices remained low. Similarly, Koç and Çavaş (2022) found that teachers had insufficient knowledge regarding laboratory safety, while Elbayoumi (2020) identified inadequate or poorly implemented safety practices.

However, previous studies have largely focused on international and tertiary education contexts, leaving Malaysian secondary education largely overlooked. Table 1 summarises international and local literature on laboratory safety across the KAP construct.

Table 1. Comparison of International and Local Studies on School Laboratory Safety Across KAP

Study	Country	Education level	Population
Hussein & Shifera (2022)	Ethiopia	Secondary	Teachers and laboratory technicians
El-Gilany et al. (2017)	Egypt	Tertiary	Laboratory technicians
Zakaria et al. (2022)	Malaysia	Tertiary	Laboratory personnel
Manuel et al. (2021)	Philippines	Tertiary	Students and faculty members
Al Mohsen (2023)	Kingdom of Saudi Arabia	Tertiary	Students and faculty members
El-Masry et al. (2021)	Kingdom of Saudi Arabia	Tertiary	Students and laboratory technicians
Garcia et al. (2024)	Philippines	Tertiary	Students

As illustrated in Table 1, previous studies on laboratory safety and KAP are predominantly situated within tertiary education contexts across various countries. In contrast, no study has been identified that assesses KAP regarding laboratory safety in Malaysian secondary schools. The absence of local, secondary-level evidence highlights a significant research gap that necessitates systematic investigation. This problem has called for a study like this to be conducted.

Next, while various instruments have been developed internationally to measure laboratory safety, their direct application in Malaysia is limited due to contextual differences in educational settings, policies, and resources. This creates a need for a valid and reliable instrument that is tailored to the Malaysian school context to ensure accurate measurement and meaningful interventions. At the same time, little is known about the safety preparedness of science teachers in Malaysia, despite their pivotal role in shaping safe laboratory environments at the secondary school level. Hence, conducting a pilot study with a small group of pre-service teachers provides not only preliminary insights into their current safety competencies but also essential evidence for refining the instrument before large-scale implementation.

This pilot phase, therefore, comes with three objectives, which are (a) to assess the KAP of pre-service secondary school science teachers in Selangor, (b) to examine the availability and functionality of laboratory safety facilities, and (c) to validate a context-specific instrument that will be used in larger-scale research. Interestingly, this study also aligns with Sustainable Development Goal 4 (Quality Education), particularly Target 4.a, which underscores the importance of establishing safe, inclusive, and effective learning environments to support high-quality education (Boeren, 2019). Governments worldwide continue to improve the quality of education through the SDGs (Saini et al., 2023). The findings of this preliminary study will support progress toward SDG 4. Hence, safer environments can promote student learning.

All in all, this pilot study is to prepare for the main study (In, 2017). Besides that, it also lays the foundation for strengthening laboratory safety culture in Malaysian schools. Its significance lies in the ability to highlight the areas in which science teachers require improvement, while also providing policymakers with a valuable reference for designing targeted professional development for science teachers to increase their safety awareness. This is in line with the study by Koç and Çavaş (2022) and the Ministry of Education Malaysia (2023), which emphasised that teachers must be sufficiently competent to provide students with a safe and conducive learning environment during class sessions.

METHODS

This study adapted the methodological stages from Zakaria, Abdullah, and Shafie (2022). Minor modifications were made to ensure alignment with the present research context. All previous studies involving the KAP model have utilised a quantitative approach, and the approach was still maintained in the present study (Gajdács et al., 2020; Peng et al., 2020; Qaraman et al., 2022). A cross-sectional survey design is employed to assess knowledge, attitudes, and practices (KAP) related to laboratory safety among pre-service secondary school science teachers in Selangor, along with the availability and functionality of school laboratory safety facilities.

As this research represents a pilot study, the sample size of 30 pre-service science teachers is appropriate for preliminary instrument validation. Pilot studies typically require between 25 and 30 participants to identify issues related to item clarity, the administration process, and initial reliability estimates (Bujang et al., 2024). The sample was selected using a random sampling technique from the population of pre-service teachers at Universiti Teknologi MARA (UiTM) who were serving their practicum, with placements distributed by the university across seven out of the ten districts in Selangor.

The inclusion criteria were: (1) pre-service teachers from Universiti Teknologi MARA (UiTM), and (2) pre-service teachers teaching science subjects, including pure science subjects such as Chemistry, Biology, and Physics. The exclusion criteria were: (1) pre-service teachers from institutions other than UiTM, and (2) those who did not teach science or pure science subjects.

Data were collected from respondents using a self-developed questionnaire tailored to the research objectives and based on the Guidelines for the Management and Safety of School Science Laboratories (PKMSS) to ensure contextual relevance. The questionnaire comprised five sections beginning with Section A, which gathered demographic information. The other four sections aligned with the KAP framework, and an additional section on the safety facility. Section B assessed participants' knowledge of laboratory safety, Section C assessed their attitudes toward laboratory safety, and Section D assessed their safety practices in the laboratory. Section E examined the availability and functionality of safety facilities in their workplace.

The knowledge section included nine multiple-choice items designed to evaluate factual understanding of laboratory safety across three domains: general safety awareness, safety equipment and facilities, and emergency preparedness and response. Responses were scored dichotomously, with correct answers assigned a score of one and incorrect answers a score of zero.

The attitude section comprised ten items measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree), which assessed beliefs and perceptions about laboratory safety. These items were grouped into three domains: importance of safety practices, responsibility and accountability, and commitment to training and continuous improvement. The practice section contained eleven items, also measured on a five-point Likert scale (1 = never to 5 = always), that captured the frequency of safety behaviours. Practices were analysed under four domains: personal safety behaviour, emergency preparedness and communication, waste management practices, and laboratory hygiene and housekeeping.

Concerning the potential central-tendency bias associated with the five-point Likert scale (Douven, 2018), caused by some respondents who may not want to respond but have to, or from those who are genuinely unable to respond to certain items (Tijmstra & Bolsinova, 2025), prompted the use of clear and straightforward language in constructing the questionnaire items to support more accurate responses.

Section E addressed the availability and functionality of safety facilities in school laboratories. This checklist included items on fire extinguishers, eyewash stations, safety showers, first-aid kits, PPE, and documentation such as chemical records, waste-disposal logs, and safety data sheets, providing a comprehensive assessment of the laboratory's safety infrastructure. The items were developed in accordance with established safety standards and reviewed by experts for clarity and relevance. Because the checklist assessed observable conditions rather than latent constructs, internal consistency reliability, such as Cronbach's alpha, was not applicable; instead, validation focused on ensuring comprehensive coverage of critical safety items in accordance with best practices.

Table 2 outlines the structure and composition of the instrument used to assess laboratory safety knowledge, attitudes, practices, and safety facilities. By detailing the components, item counts, and question types, it confirms the instrument's alignment with the research objectives to comprehensively measure all relevant aspects of laboratory safety among pre-service teachers.

Table 2. Section within the Instrument

Component	Total Items	Types of items
Section A: Demographic factors	-	-
Section B: Knowledge of laboratory safety	12 items	Multiple choice question (MCQ)
Section C: Attitudes towards laboratory safety	10 items	Five-point Likert scale
Section D: Safety practices in the laboratory	11 items	Five-point Likert scale
Section E: Availability and functionality of safety facilities	15 items	Check list

Content validity for the questionnaire was established through expert judgment by panels of experienced science educators and laboratory specialists. The experts evaluated the clarity, relevance, and coverage of each item (Beck, 2020; Almanasreh et al., 2022). Their feedback informed refinement of wording, sequence, and domain classification. Then, reliability testing was conducted using Cronbach's alpha for the attitude and practice sections. The type of reliability tested was internal consistency, as it indicates how well the items measure the same construct (Taber, 2018).

Quantitative data were collected because the approach used focuses on measurement (Leavy & Patricia, 2017). Descriptive statistics (mean, standard deviation, frequencies, and percentages) were used to summarise demographic information and responses. Knowledge items were analysed using difficulty and discrimination indices to evaluate their quality as test items. Reliability of the attitude and practice scales was assessed using Cronbach's alpha. Finally, the overall levels of knowledge, attitude, and practice were assessed.

The scoring system used to assess the level of knowledge, attitude, and practice (KAP) classified respondents into low, moderate, and high levels. For the knowledge section, respondents were categorised based on their total mean score, either low (<30%), moderate (30–70%), or high (>70%), adapted from Zakaria et al. (2022) with modifications. For the attitude and practice section, the mean Likert-scale score for each respondent was calculated, and respondents were classified into low (1.00-2.33), moderate (2.34–3.66), and high (3.67–5.00) categories. After sorting respondents into the categories for each section, the numbers were converted to percentages, reflecting the levels of knowledge, attitudes, and practices, respectively.

To quantify the magnitude of the knowledge–attitude–practice (KAP) gap, effect size analyses were conducted using a within-subjects approach. Knowledge, attitude, and practice scores were first standardised to percentage values to account for differences in scale and number of items across domains. Paired-sample effect sizes were then calculated using Cohen's *d* for dependent measures (d_x), derived from the mean difference divided by the standard deviation of the difference scores. This method is appropriate for repeated-measures KAP data and enables interpretation of the practical significance of domain differences beyond descriptive statistics. Effect sizes were interpreted using conventional benchmarks, with values of 0.20, 0.50, and 0.80 representing small, moderate, and large effects, respectively. All analyses were conducted using IBM SPSS Statistics, with effect sizes computed based on SPSS output. Ethical approval for the study was obtained from the institutional research ethics committee with reference number REC/11/2025 (PG/MR/615). Participation was voluntary, and informed consent was obtained from all respondents prior to data collection. Anonymity and confidentiality were strictly maintained throughout the research process.

RESULTS AND DISCUSSION

Expert validation confirmed that the KAP laboratory safety questionnaire demonstrated strong internal consistency and content validity. All 12 knowledge items showed acceptable to good difficulty levels (p = 0.50–0.80), while the Attitude and Practice sections recorded Cronbach's alpha values of 0.901 (standardised α = 0.920) and 0.905 (standardised α = 0.910), respectively, exceeding the recommended threshold of 0.8. These results indicate that the instrument reliably measured the intended constructs with clarity and coherence.

Table 3 presents the demographic background of the respondents involved in the pilot study.

Table 3. Demographic Backgrounds

Item	n	Percentage (%)
Gender		
Male	7	23.3
Female	23	76.7
Age	24.10±0.6	
Attended training		
Yes, within the last year	2	6.7
Yes, but more than a year ago	6	20.0
No, I have never attended	22	73.3
Managing lab		
Biology	15	50
Chemistry	9	30
Physics	5	16.7
Science	19	63.3

The sample comprised 30 participants, with the majority being female (76.7%) and an average age of 24.1 years. Most had never attended laboratory safety training (73.3%), while only a small proportion had received training within the last year (6.7%). In terms of laboratory management, the highest proportion of respondents was responsible for general science laboratories

(63.3%) and biology laboratories (50%). These findings suggest that while the respondents are actively involved in managing laboratories, their limited exposure to formal training may indicate insufficient preparedness for safety-related responsibilities.

Table 4 summarises the difficulty and discrimination indices for the knowledge items. This analysis is important to determine whether the items effectively differentiate between respondents with high and low levels of safety knowledge.

Table 4. Difficulty Index and Discrimination Index for the Knowledge Section

	Item	Difficulty Index	Discrimination Index
K1: General laboratory safety awareness	Q1	0.57	0.50
	Q2	0.60	0.63
	Q3	0.60	0.75
	Q4	0.50	0.63
K2: Safety equipment and facility	Q5	0.67	0.63
	Q6	0.57	0.63
	Q7	0.77	0.50
	Q8	0.70	0.38
K3: Emergency preparedness and response	Q9	0.67	0.63
	Q10	0.67	0.50
	Q11	0.37	0.38
	Q12	0.77	0.63

Item analysis shown in Table 4 for the knowledge section showed that all 12 questions fell within the acceptable difficulty range (0.50–0.80), indicating that none were excessively easy or difficult. Discrimination indices ranged from 0.30 to 0.80, with one item demonstrating excellent discrimination (Q7 and Q12 = 0.77), nine items showing strong discriminative ability (≥0.40), and one item within the acceptable range (0.30).

The pilot test data for the attitude and practice sections were examined using Cronbach's alpha analysis, and the findings are shown in Table 5.

Table 5. Item-Total Statistics: Items and Values in Components of Attitude and Practice Towards Laboratory Safety

Component	Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha Overall
A1: Importance of safety practices	Q2	42.80	10.579	0.693	0.888	0.901
	Q3	42.77	10.461	0.777	0.884	
	Q4	42.77	10.461	0.777	0.884	
	Q5	42.77	10.668	0.696	0.889	
A2: Responsibility and accountability for safety	Q7	42.80	10.786	0.512	0.900	
	Q8	42.73	10.409	0.851	0.881	
	Q9	42.67	11.126	0.678	0.892	
A3: Commitment to training and continuous improvement	Q10	42.73	10.547	0.793	0.884	
	Q11	42.93	9.857	0.534	0.908	
	Q12	42.83	10.006	0.577	0.900	

P1: PPE and Safe Handling Practices	Q1	42.10	39.748	0.557	0.901	0.905
	Q2	42.10	40.852	0.480	0.905	
	Q4	42.13	37.637	0.741	0.891	
P2: Emergency Preparedness	Q5	41.97	39.826	0.696	0.894	
	Q7	41.83	40.075	0.685	0.895	
	Q8	42.43	36.668	0.633	0.900	
	Q10	42.13	37.706	0.700	0.893	
P3: Laboratory hygiene and housekeeping	Q12	41.90	39.955	0.619	0.898	
	Q13	42.03	37.068	0.759	0.890	
	Q14	42.07	38.685	0.722	0.892	
	Q15	41.63	41.964	0.629	0.899	

The finding demonstrated strong internal consistency across both components. Within the three domains, all items contributed positively to the scale's reliability. The first domain, importance of safety practices (Q2–Q5), recorded corrected item–total correlations ranging from 0.693 to 0.777, with alpha values if deleted between 0.884 and 0.889, confirming the adequacy of the items. In the second domain, responsibility, and accountability for safety (Q7–Q9), item–total correlations ranged from 0.512 to 0.851, again within acceptable limits. The third domain, commitment to training and continuous improvement (Q10–Q12), yielded correlations between 0.534 and 0.793, and none of the items showed potential for removal.

Similarly, the practice section produced a Cronbach's alpha of 0.905 (standardised α = 0.910), also above the 0.80 benchmark. Across its domains, PPE, and safe handling practices (Q1, Q2, Q4) displayed correlations from 0.480 to 0.741, the emergency preparedness domain (Q5, Q7, Q8, Q10) ranged from 0.633 to 0.700, and laboratory hygiene and housekeeping (Q12–Q15) ranged from 0.619 to 0.759. Importantly, the deletion of any item in either the attitude or practice section did not improve the overall alpha values, indicating that all items were reliable and appropriate for retention. Table 6 presents the distribution of laboratory safety knowledge, attitudes, and practices among respondents across overall scores and subdomains.

Table 6. Knowledge, Attitude, and Practice of Pre-Service Science Teachers

Domain	Low n (%)	Moderate n (%)	High n (%)	Mean ± SD
Knowledge overall (n = 12 items)	5 (16.7)	11 (36.7)	13 (43.3)	8.5±3.6
General laboratory safety awareness	12 (40.0)	1 (3.3)	16 (53.3)	2.3±1.3
Safety equipment and facility	4 (13.3)	8 (26.7)	17 (56.7)	2.7±1.2
Emergency preparedness and response	13 (43.3)	10 (33.3)	13 (43.3)	2.5±1.1
Attitude overall (n = 10 items)	–	–	30(100.0)	4.8±0.4
Importance of safety practices	–	–	30(100.0)	4.7±0.4
Responsibility & accountability	–	–	30(100.0)	4.8±0.3
Commitment to training & improvement	–	2(6.7)	28(93.3)	4.7±0.5
Practice overall (n = 11 items)	–	7(23.3)	23(76.7)	4.2±0.6
PPE and safe handling practices	1 (3.3)	8(26.7)	21(70.0)	4.1±0.7
Emergency preparedness	–	7(23.3)	23(76.7)	4.1±0.7
Laboratory hygiene & housekeeping	–	5(16.7)	25(83.3)	4.3±0.6

For knowledge, less than half of the respondents demonstrated a high level of overall knowledge (43.3%), while 36.7% were categorised as having a moderate level and 16.7% as having a low level (mean = 8.5, SD = 3.6). Subdomain analysis revealed comparatively better understanding of safety equipment and facility, where more than half of the respondents (56.7%) achieved high scores (mean = 2.7, SD = 1.2). In contrast, general laboratory safety awareness showed greater variability, with 40.0% of respondents scoring at a low level and only 53.3% attaining high scores (mean = 2.3, SD = 1.3).

Knowledge related to emergency preparedness and response was more evenly distributed, with 43.3% of respondents in both the low and high categories and 33.3% at a moderate level (mean = 2.5, SD = 1.1), indicating inconsistent understanding across this subdomain. Attitudes toward laboratory safety were uniformly high, with all respondents scoring in the high category overall (mean = 4.8, SD = 0.4). Subdomains reflected similar trends: 100% rated highly on the importance of safety practices and responsibility, while 93.3% were high on commitment to training, with only 6.7% at a moderate level (mean = 4.7, SD = 0.5). Practices were slightly less consistent, with 76.7% reporting high adherence and 23.3% moderate adherence (mean = 4.2, SD = 0.6). Laboratory hygiene and housekeeping emerged as the strongest practice area (83.3% high, mean = 4.3, SD = 0.6), followed by emergency preparedness (76.7% high) and PPE handling (70.0% high), though a small group (3.3%) reported low PPE compliance (mean = 4.1, SD = 0.7).

Table 7 presents the effect size analysis of KAP gaps from the respondents. Scores from the table were standardised to percentages before analysis. Cohen's *d* values represent paired-sample effect sizes (d_x). Interpretation followed Cohen's guidelines. Effect size analysis revealed substantial discrepancies between the knowledge, attitude, and practice domains. A large effect size was observed for the knowledge–practice comparison (Cohen's *d* = 0.75), indicating a meaningful gap between respondents' knowledge levels and their reported laboratory safety practices. Similarly, the attitude–practice comparison demonstrated a large effect size (*d* = 0.79), suggesting that highly positive attitudes toward laboratory safety were not consistently translated into actual practice.

Table 7. Effect Size Analysis of Knowledge–Attitude–Practice (KAP) Gaps among Pre-Service Science Teachers (n = 30)

Comparison	Mean Score (%) Domain 1	Mean Score (%) Domain 2	Mean Difference	Cohen's d (paired)	Effect Magnitude
Knowledge vs Practice	61.94 ± 23.64	82.76 ± 12.11	20.82	0.75	Large
Attitude vs Practice	93.28 ± 7.19	82.76 ± 12.11	10.52	0.79	Large
Knowledge vs Attitude	61.94 ± 23.64	93.28 ± 7.19	31.34	1.26	Very large

The largest discrepancy was observed between knowledge and attitude scores, with a very large effect size (*d* = 1.26). This finding indicates a pronounced divergence between respondents' understanding of laboratory safety principles and their attitudinal endorsement of safe practices. Collectively, these results confirm the presence of a substantial KAP gap, particularly highlighting misalignment between cognitive, affective, and behavioural components of laboratory safety.

Table 8 summarises the availability and functionality of safety facilities across school laboratories. Overall availability was high (87.5%), with most laboratories reporting the presence of essential items such as fire extinguishers (93.3%), PPE (90.0%), safety showers (86.7%), and chemical storage facilities (93.3%). However, functionality was markedly lower, with an overall score of only 32.7%. While fire extinguishers were present in nearly all laboratories, only 70% were functional. Similar discrepancies were observed for eyewash stations (70% available, 60% functional) and safety showers (86.7% available, 56.7% functional). Documentation and record-keeping showed the weakest performance, with Safety Data Sheets functional in only 36.7% of laboratories and chemical expiry records in 40.0%. In contrast, storage of instruments (93.3%) and inventory systems (90.0%) were well maintained.

Table 8. Availability and Functionality of Safety Items in the Laboratory. Data Presented in Actual Numbers and Percentages

Item	Availability	Functionality
Safety signs and labels	27(90%)	14(46.7)
Personal Protective Equipment (PPE)	27(90)	18(60)
Fire extinguisher	28(93.3)	21(70)

Eyewash	21(70)	18(60)
Safety shower	26(86.7)	17(56.7)
First aid kit	25(83.3)	17(56.7)
Record of waste disposal	24(80)	14(46.7)
Storage of instruments and tools	28(93.3)	28(93.3)
Chemical's storage	28(93.3)	15(50)
Chemical's record	28(93.3)	15(50)
Safety data sheet (SDS)	24(80)	11(36.7)
Incident/accident records	26(86.7)	14(46.7)
Instruments usage/damage records	27(90)	14(46.7)
Chemical's expiry records	28(93.3)	12(40)
Inventory	27(90)	27(90)
Score overall	87.5%	32.7%

This pilot study discusses the validity of a context-specific instrument for assessing laboratory safety knowledge, attitudes, and practices (KAP) among Malaysian pre-service science teachers who are doing practicum, alongside preliminary findings on their safety competencies and laboratory facility readiness. The discussion interprets the psychometric strength of the instrument and examines emerging KAP patterns, particularly gaps between knowledge, attitudes, and practice, within the context of existing laboratory safety literature and Malaysian secondary school settings.

Based on expert feedback, several items were refined in wording and clarity, resulting in a final version comprising twelve knowledge items, ten attitude items, eleven practice items, and a section assessing the availability and functionality of laboratory safety facilities. This process aligns with established practices in instrument development, where expert consensus underpins content validity (Boateng et al., 2018; Yusoff, 2019). Overall, the validated instrument provides a contextually relevant and psychometrically robust tool for assessing laboratory safety among pre-service science teachers in Malaysia.

These results confirm that the items were both appropriately challenging and effective in differentiating respondents with higher and lower safety knowledge, thereby supporting their retention in the final instrument. Such values are essential in instrument development as they ensure meaningful construct measurement while avoiding ceiling effects (DeVellis & Thorpe, 2022). In addition, the analysis presented in Table 4 shows that knowledge items with acceptable difficulty and discrimination indices demonstrate that the instrument effectively differentiates levels of laboratory safety knowledge among pre-service teachers. This directly addresses the research question regarding knowledge by confirming that respondents possess varying, measurable levels of understanding of key safety domains.

For the attitude section, Cronbach's alpha was 0.901 (standardised $\alpha = 0.920$), surpassing the commonly accepted threshold of 0.70 (Taber, 2018; Hussey et al., 2025). Reliability testing evidenced the strength of the Attitude and Practice sections, with Cronbach's alpha coefficients exceeding 0.90 and demonstrating coherence without redundancy across subdomains. The 'Cronbach's alpha if item deleted' analysis was used to evaluate whether the removal of any item would improve the internal consistency of the Attitude and Practice scales. For both the Attitude and Practice scales, no item deletion resulted in a meaningful improvement in the overall reliability coefficients, as all items demonstrated acceptable corrected item–total correlations and contributed positively to the constructs. This item-retention decision aligns with established psychometric practices, where items are retained when they enhance measurement precision and conceptual coverage. Importantly, retaining all items did not compromise construct validity, as the items were well aligned with expert-defined domains. The final retained items preserved full representation of key laboratory safety components, such as the importance of safety practices, responsibility and accountability, emergency preparedness, and laboratory hygiene, while producing strong reliability coefficients. Collectively, these findings confirm the psychometric robustness and conceptual integrity of the refined KAP instrument.

Taken together, these results demonstrate that the final instrument is both valid and reliable for assessing laboratory safety in the Malaysian school context. This distinguishes the present study from international KAP research, where instruments are often adapted from different cultural or institutional settings (Hussein & Shifera, 2022; Zakaria et al., 2022). By providing a locally developed and psychometrically tested tool aligned with national guidelines and resources, this study establishes a reliable foundation for larger-scale evaluations of safety competencies and supports the development of targeted interventions for strengthening teacher preparation in laboratory safety. The strong internal consistency in Table 5, demonstrated by high Cronbach's alpha values across attitude and practice items, confirms the reliability of the instrument in measuring these constructs. This supports the research question on attitudes and practices by validating that the instrument captures consistent and meaningful data about pre-service teachers' safety-related beliefs and behaviours.

Table 6 shows that the distribution of results reflects moderate-to-high levels of laboratory safety knowledge and universally positive attitudes, alongside more variable practice levels among pre-service science teachers. These findings address the research problem by demonstrating a clear gap between knowledge and attitudes on one hand, and the consistent enactment of safe laboratory practices on the other, highlighting areas where teacher preparation may require further reinforcement. The results indicate that while fewer than half of the respondents achieved a high level of overall knowledge, attitudes toward laboratory safety were uniformly positive across all domains.

Subdomain analysis further suggests that knowledge related to safety equipment and facilities was comparatively stronger, whereas general laboratory safety awareness and emergency preparedness showed greater variability, indicating uneven understanding across safety domains. In terms of practice, although most respondents reported high adherence overall, a notable proportion demonstrated only moderate compliance, particularly in PPE use, where a small group reported low adherence. This pattern is consistent with previous studies reporting suboptimal PPE compliance despite adequate awareness and training (Ayi & Hon, 2018; Okebukola et al., 2020). The observed knowledge–practice gap mirrors trends reported in earlier research, where strong awareness and positive attitudes do not always translate into consistent safety behaviours (Hussein & Shifera, 2022). Similar discrepancies have also been documented among Malaysian university laboratory personnel, where high awareness of safety standards was accompanied by weaker adherence to safety practices (Zakaria et al., 2022). Collectively, these findings suggest that although pre-service teachers value laboratory safety, translating knowledge and attitudes into consistent practice requires sustained hands-on training, regular monitoring, and stronger institutional support mechanisms.

The effect size analysis confirms the presence of a substantial knowledge–attitude–practice (KAP) gap among school science teachers. Although attitudes toward laboratory safety were uniformly positive and reported practices were relatively high, the large knowledge–practice and attitude–practice effect sizes indicate that cognitive understanding and attitudinal endorsement were not consistently translated into safe laboratory behaviour. This finding supports previous KAP research demonstrating that knowledge and attitudes alone are insufficient predictors of practice, particularly in safety-related contexts where situational constraints and habitual routines influence behaviour (Launiala, 2009; McEachan et al., 2016).

The very large discrepancy between knowledge and attitude suggests that safety may be strongly endorsed at a normative or value-based level despite gaps in technical understanding. From an educational perspective, this highlights the limitation of predominantly knowledge-based safety training. Consistent with science education literature, more practice-oriented interventions such as hands-on safety simulations, structured drills, and continuous professional development are likely to be more effective in bridging the KAP gap than theoretical instruction alone (Hofstein & Lunetta, 2004; Burke et al., 2006). These findings underscore the need for institutional strategies that support the translation of safety knowledge and attitudes into sustained laboratory practice.

These findings highlight a substantial gap between provision and operational readiness, particularly for emergency equipment and documentation. This directly addresses the research question on laboratory safety facilities by identifying a significant discrepancy between provision and operational readiness, which potentially compromises safety compliance in school settings. This discrepancy between availability and functionality mirrors trends reported internationally, such as in Sweden and Nepal, where insufficient maintenance limited laboratory safety readiness despite equipment being present (Kandel et al., 2017; Schenk et al., 2018). Similar gaps have also been observed in Malaysia, where laboratory safety initiatives are often constrained by limited resources and inconsistent enforcement of maintenance protocols (Ali et al., 2018). Addressing these shortcomings requires a resourceful investment in building management (Wiriyakraikul et al, 2022). Collectively, these results underscore the importance of a validated, context-specific instrument to monitor laboratory safety while emphasising the urgent need to strengthen both teacher preparedness and institutional systems.

Overall, the results across Tables 6–8 indicate that pre-service science teachers display uneven but generally adequate laboratory safety knowledge, uniformly positive attitudes, and mostly high reported safety practices, although variability persists across specific domains. In particular, inconsistencies in general safety awareness, PPE compliance, and the functionality of laboratory safety facilities appear to coincide with the substantial knowledge–attitude–practice gaps identified through effect size analysis. These patterns suggest that positive safety orientations may be insufficient on their own to ensure consistent safe laboratory behaviour, especially when technical understanding and institutional readiness are uneven. Within this context, the findings highlight the importance of considering both individual preparedness and environmental conditions when interpreting laboratory safety practices among pre-service teachers.

CONCLUSION

This pilot study developed and validated a context-specific instrument for assessing laboratory safety knowledge, attitudes, and practices (KAP) among Malaysian pre-service science teachers and examined preliminary patterns in safety competencies and laboratory facility readiness. The instrument demonstrated strong content validity and internal consistency across attitude and practice domains, confirming its suitability for use in the Malaysian school context. Findings from the KAP analysis showed uneven but measurable knowledge levels, uniformly positive attitudes, and generally high yet variable safety practices. Importantly, effect size analyses revealed substantial gaps between knowledge, attitudes, and practices, indicating that strong attitudinal endorsement of laboratory safety does not consistently translate into safe laboratory behaviour. In parallel, facility assessments showed a marked discrepancy between the availability and functionality of safety equipment and documentation, suggesting that institutional readiness may further constrain the enactment of safe practices. Taken together, the findings highlight laboratory safety as a multidimensional issue shaped by individual competencies and systemic conditions rather than by knowledge or attitudes alone. Several limitations should be acknowledged. As a pilot study with a small sample drawn from a single institution and limited geographic coverage, the findings are exploratory and not intended to be generalisable. The study employed a cross-sectional and primarily descriptive design, limiting causal interpretation of relationships between KAP domains. In addition, attitudes and practices were measured using self-report instruments, which may be subject to social desirability and response bias, potentially inflating reported safety compliance. These limitations should be considered when interpreting the results. Despite these constraints, the study offers important implications for teacher education and school laboratory management. Integrating structured laboratory safety KAP training into pre-service teacher preparation programmes, such as the Postgraduate Diploma in Education (PPG), may help strengthen the translation of safety knowledge and attitudes into consistent practice. At the institutional level, regular and systematic audits of laboratory safety facilities, particularly emergency equipment, safety documentation, and maintenance records, may improve operational readiness. Future research should involve larger, multi-institutional samples to enable inferential analyses and examine predictors of laboratory safety practice. Longitudinal and intervention-based studies are also recommended to evaluate the effectiveness of targeted safety training in reducing knowledge–practice gaps. The validated instrument developed in this study provides a robust foundation for such work and supports broader efforts to promote safe learning environments in line with Sustainable Development Goal 4 (Quality Education).

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