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Research Article

The Impact of Safety Culture on Safety Behavior in University Chemistry Laboratories

Xing Gao[a], Jirawan Deeprasert[a],*

[a]*Rattanakosin International College of Creative Entrepreneurship, Rajamangala University of Technology Rattanakosin, Bangkok 10700, Thailand.*

**Corresponding author. Email: jirawan.dee@rmutr.ac.th*

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ABSTRACT

This study aims to explore the relationships between safety culture constructs and safety behaviors, and to analyze the mediating roles of safety awareness, behavioral attitudes, and subjective norms. We collected data from 499 university laboratory personnel through a combination of online and offline methods, and processed the data using descriptive statistical analysis, reliability and validity analysis, and structural equation modeling.esults show that safety values, safety attitudes, and safety perceptions significantly impact safety behavior, both directly and indirectly, with safety attitudes acting as a key mediator in translating safety culture into behavior. Safety awareness also plays a crucial role in enhancing safety behavior. Notably, the study reveals that subjective norms have a less significant role than anticipated in shaping safety behaviors, suggesting that while external social factors are relevant, internal attitudes and awareness are more influential in a laboratory setting. These findings highlight the importance of fostering a safety culture through both individual attitudes and organizational strategies, emphasizing the need for comprehensive safety management systems in university laboratories.

Keywords: : University laboratories; Safety culture; Safety behavior; Safety attitude; Structural Equation Modeling (SEM)

INTRODUCTION

In recent years, the rapid expansion of higher education institutions has led to significant growth in laboratory infrastructure, particularly in chemistry laboratories, which are vital for scientific research, technological innovation, and the cultivation of future scientific talent (Manyilizu, 2023). However, the inherent risks associated with laboratory operations have made laboratory safety a major concern worldwide. Incidents such as chemical spills, explosions, and fires not only pose severe health and safety hazards but also highlight the pressing need to establish a robust safety culture within laboratories (Abedsoltan & Shiflett, 2024). There is a significant proportion of laboratory accidents stem from human factors, including unsafe behaviors, insufficient awareness, and weak safety values (Li et al., 2021). These issues underscore the importance of developing an effective laboratory safety culture to mitigate risks and ensure a safer working environment.

Laboratory safety culture encompasses shared values, attitudes, perceptions, and behaviors that determine the commitment to safety practices within an organization (Felix Orikpete & Raphael Ejike Ewim, 2024). Unlike safety regulations and protocols, which focus on technical aspects and compliance, safety culture reflects deeper organizational and individual-level commitments to safety (Bernard, 2021). Existing research indicates that a positive safety culture can significantly reduce unsafe behaviors by fostering safety awareness, enhancing safety attitudes, and promoting a shared sense of responsibility among personnel (Nævestad et al., 2021). However, despite its recognized importance, laboratory safety culture in higher education institutions remains underdeveloped at present (Adhikari & Shrestha, 2023).

Several challenges remain critical. First, although safety management systems have been widely implemented, the respective underlying safety values, defined as individuals' beliefs and motivations toward safety, have garnered limited academic attention (Tetzlaff et al., 2021). Safety values form the foundation of safety culture and influence individuals' decisions to adopt safe behaviors, yet their role in laboratory safety remains insufficiently explored (Felix Orikpete & Raphael Ejike Ewim, 2024). Secondly, there is a lack of empirical research that systematically examines the pathways through which safety culture, particularly safety values, safety attitudes, and safety perceptions, influence laboratory safety behaviors (Marquardt et al., 2021). Understanding these mechanisms is important for the development of effective interventions aimed at improving safety outcomes. Thirdly, existing studies have failed to clearly address the mediating roles of safety awareness, subjective norms, and behavioral attitudes in shaping safety behaviors (Guerin & Toland, 2020). These factors are crucial in the translation of safety culture into concrete actions; however, their interactions are not clear in the context of laboratory safety.

Addressing these gaps is important for the advancement of both academic understanding and practical approaches to laboratory safety. This research will investigate the impact of laboratory safety culture on safety behaviors among university chemistry laboratory personnel. Specifically, the objectives of this research are:

(1) to investigate the relationships among safety values, safety attitudes, safety perceptions, and laboratory safety behaviors;

(2) to explore the mediating roles of safety awareness, subjective norms, and behavioral attitudes in these relationships.

The structure of the paper is as follows: Section 2 presents a critical review of the literature and theoretical frameworks, pinpoints the key variables, and identifies gaps in research. Section 3 outlines the methodology adopted in the research, survey design, data collection, and analysis techniques. Section 4 presents the empirical findings, while Section 5 discusses the theoretical contributions and practical implications of the results. Finally, Section 6 concludes with recommendations to improve laboratory safety culture and promote safer behaviors among laboratory personnel.

LITERATURE REVIEW

Geller's safety culture framework emphasizes the critical role of shared safety values, attitudes, and perceptions in shaping individual and organizational safety behaviors (Geller, 1996). The theory suggests that fostering a positive safety culture requires instilling strong safety values, which influence individuals' behavioral attitudes and compliance with safety protocols. Empirical evidence from industrial environments has demonstrated that embedding safety values into workplace culture effectively reduces accident rates and promotes safe behavior among employees (Zakzeski, 2009). Additionally, studies have confirmed that safety values contribute to the formation of safety attitudes and awareness, which are essential for hazard recognition and risk mitigation (Khalid et al., 2021).

Accident Causation "2-4" Model: The model identifies human factors and system deficiencies as the root causes of safety incidents. It explains that safety awareness can provide a critical role in avoiding accidents, as it permits one to recognize risks and adopt precautions (Fu et al., 2020; Khalid et al., 2021). Previous studies in the industrial and organizational settings in terms of safety have reported that safety awareness mediates between safety culture and behaviors in reducing unsafe actions and accidents (Kilcullen et al., 2022). The model further stipulates that safety awareness can be considerably heightened through structured training and organized safety management, hence ensuring consistent safety practices and behavior.

The Theory of Planned Behavior (TPB) posits that individual behavior is determined by three key constructs: behavioral attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991). Behavioral attitudes refer to individuals' evaluations of a specific behavior, while subjective norms encompass perceived social pressures to engage in the behavior (Nogueira et al., 2023). Perceived behavioral control reflects individuals' confidence in their ability to perform the behavior under specific conditions. TPB has seen wide validation across a range of safety contexts, from industrial safety management to preventive health behaviors, with attitudes, norms, and control beliefs proving key predictors of behavioral intentions in these settings (Zeng et al., 2021). In safety management studies, TPB constructs have proved useful in explaining the adoption of safety practices, compliance with regulations, and the reduction of accidents (Guerin & Toland, 2020).

Values are considered motivational constructs for the reason that their activation, whether by conscious means or through situational cues, leads to the emergence of behaviors. According to Sagiv and Roccas (2021), the more important the value is, the higher the degree of accessibility and, therefore, salience it has in driving behaviors. Research within industrial safety contexts also points out the place of safety values in fostering safe behaviors. For example, Zakzeski (2009) identified that appropriate safety values among the chemists and operators bring up the culture of ensuring safety in an industrial chemical plant. Safety values, most especially those to do with safety ethics, are considered by Tear et al. (2020) to be the heart of human factor regulation in safety culture. It is because safety values stir attitudes, norms, and awareness. Though the latter has been related to safety values in industrial contexts, no empirical evidence supports its validation within laboratory safety in higher education. Based on the above, the following hypotheses can be stated:

H1: Safety values have a positive effect on the experimenters' behavioral attitudes.

H2: Safety values have a positive effect on the experimenters' subjective norms.

H3: Safety values have positive impacts on experimenters' safety awareness.

Safety attitude is defined as an individual's belief in the desirability of performing safety-related behavior; this belief will influence behavior (Guerin & Toland, 2020). Improved safety attitudes have been verified to be well associated with standardized safety behavior in workplaces (Chen et al., 2021). Moreover, safety attitude influences safety awareness and subjective norms by forming beliefs and their reactions towards the management's safety practices Felix Orikpete & Raphael Ejike Ewim, 2024).In nuclear power plants, for example, safety attitudes have a dual role: they enhance belief in behavior and attitude while fostering adherence to safety regulations due to social and managerial pressures (Schöbel et al., 2022). These paths suggest that safety attitudes may solidify psychological characteristics, amplify behavioral vigilance, and create consistency between norms and safety practice. This particular influence of safety attitudes in the context of a lab environment where experimental norms and safety consciousness is very essential has not been appropriately checked.

Based on these, the following hypotheses have been obtained:

H4: Safety attitude positively influences the experimentalists' behavioural attitude.

H5: Safety attitude positively influences the subjective norm of the experimenters.

H6: Safety attitudes positively affect the safety awareness of experimenters.

Safety perceptions refer to people's subjective evaluation of the safety risks, management systems, and the general safety environment (Akalin et al., 2022). Research has shown that safety perceptions significantly affect individuals' awareness of hazards, attitudes toward safety practices, and the formation of subjective norms (Kurata et al., 2023). In organizational safety research, inadequate safety perceptions have been identified as a contributing factor to unsafe behaviors, accidents, and poor safety performance (Liang et al., 2022).The presence of effective safety management systems improves safety perceptions, which subsequently influence safety attitudes, normative pressures, and hazard recognition (Nævestad et al., 2021). Although the relationship between safety perceptions and the latter constructs has been found to be valid in the context of industrial settings, the same is yet to be tested in laboratory safety behaviour within higher education institutions. Therefore, based on above discussion following hypotheses are advance:

H7: Safety Perceptions positively influence the Behavioural Attitudes of the Experimenter

H8: Safety Perceptions positive influence the Subjective Norms of the experimenter.

H9: Safety perceptions positively affect the safety awareness of experimenters.

The Theory of Planned Behavior maintains that one's attitude, subjective norms, and perceived control directly influence one's behavioral intentions, which in turn determine one's actual behavior (Ajzen, 2019). Behavioral attitudes refer to an individual's positive or negative assessment of a certain behavior, while subjective norms reflect the perceived social pressures to perform or not to perform that behavior (Wu et al., 2023). Safety awareness is defined as the knowledge of the individual about hazards and the ways of prevention. Empirical findings have identified that such factors directly affect the formation of safety behaviors. On direct influences, it has been found that subjective norms and commitment to safety significantly predicted safety behavior among laboratory personnel by Abdullah and Abd Aziz 2020, while in Aschwanden et al. (2021), both behavioral attitudes and subjective norms independently influence an individual's preventive behavior. Despite these findings, the direct relationships between these constructs and safety behaviors in university laboratory settings remain under-explored. Based on this, the following hypotheses are put forward:

H10: Behavioral attitudes of experimenters have a positive influence on safety behavior.

H11: Subjective norms of experimenters have a positive influence on safety behavior.

H12: Safety awareness of experimenters has a positive influence on safety behavior.

Behavioral attitude refers to the overall evaluation—positive or negative—that an individual holds regarding performing a certain behavior, which in turn affects his or her intention to perform the behavior (Ajzen, 2019). Being one of the fundamental constructs of TPB, behavioral attitudes most of the time serve as mediators between the relations involving the effect of some other factors and actual behavior. Previously, a number of research have validatated that behavioural attitutudes may very well play as the mediators between variables for various cases including Workplace safety and Previnentive Health behaviour. For example, Owusu Danso et al. (2022) established how safety culture variables like safety values and safety perceptions influence safety behavior indirectly by influencing attitude toward the behavior. Similarly, Aschwanden et al. (2021) found attitudes also acted as a mediator between what individuals believed and their practice in taking precautionary measures in view of a number of issues.

Whereas these associations have been widely studied within industrial safety and organizational behavior contexts, there is rather rare empirical evidence with regard to the role of behavioral attitude mediators in the higher education institution laboratory safety context. The specific pathways-that is, the concept of how safety values and safety attitudes and safety perceptions influence experimenters' safety behavior through behavioral attitudes themselves-have not been tested. Based on this, the following hypotheses are proposed:

H13 : Attitudes of behavior will mediate between the relations of the value of safety and behavioral safety.

H14: Behavioural attitudes mediated the associations between safety attitude and safety behaviour

H15 : Behavioural attitudes mediated associations between safety perception and safety behavior

Subjective norms According to Ajzen 2019 refer to perceived social pressures one is facing to undertaking a certain kind of behavior or not. Influential others, normally peers, managers, or other forms of persons of authority, have these norms influenced and mostly engage between external variables and behavioral responses as mediating influences. Indeed, Abdullah and Abd Aziz (2020) investigated lab safety behaviors among students and found that subjective norms play a significantly mediating role in the relationship of safety knowledge with safety behavior, indicating the importance of social influences in shaping adherence to safety practices. Likewise, Aschwanden et al. (2021) also confirmed that subjective norms acted as a bridge between individuals' safety-related beliefs and their preventive behaviors. In spite of this evidence, there is still a lack of research on the mediating role of subjective norms in the context of laboratory safety behavior in higher education institutions. Specifically, the influences of safety values, safety attitude, and safety perception on safety behavior through subjective norms remain to be empirically proven. From this, the following hypotheses are made:

H16: Subjective norm mediates the relationship between safety values and safety behavior.

H17: Subjective norm mediates the relationship between safety attitude and safety behavior.

H18: The subjective norm mediates the relationship between safety perception and safety behavior.

Safety awareness can be defined as a person's knowledge of possible hazards, risks, and measures of prevention that are needed in a particular environment. It forms a part of safety culture in that safety awareness helps develop one's ability to realize hazards and make appropriate action to avoid unsafe behaviors (Bisbey et al., 2019). In the studies related to organizational safety, it has widely been recognized that safety awareness mediates the relationship between safety culture factors and safety behavior (Adjekum & Tous, 2020). For instance, Liu et al. (2020) found that safety awareness mediated the influence of safety perceptions on employees' adherence to safety protocols in industrial settings. In a similar vein, other studies have found that safety awareness mediates the influence of safety values and attitudes on behavioral outcomes since it encourages the recognition of risks and the taking of precautionary measures (Meng et al., 2021).

The mediating function in industrial safety environments is empirically established, while in a higher education laboratory safety perspective, it has yet to be explored. The ways safety values, safety attitude, and safety perception mechanisms play their role in experimenters' safety behavior through the mediating role of safety awareness is still theoretically established and empirically unexplored. In addition, based on the discussion above, the following hypothesis is developed:

H19: Safety awareness mediates the relationship between safety values and safety behavior.

H20: Safety awareness mediates the relationship between safety attitude and safety behavior.

H21: Safety awareness mediates the relationship between safety perception and safety behavior.

Figure 1 presents a model integrating safety values, safety attitudes and safety perceptions that may influence safety behavior of laboratory experimenters. This model includes three important mediating variables, namely, behavioral attitudes, subjective norms, and safety awareness to depict how the dimensions of safety culture lead to safety behavior. This framework therefore comprehensively highlights the direct and mediated relationships of mechanisms that promote safer practices in laboratory environments, thus offering valuable insights into the enhancement of safety culture and behavioral compliance.

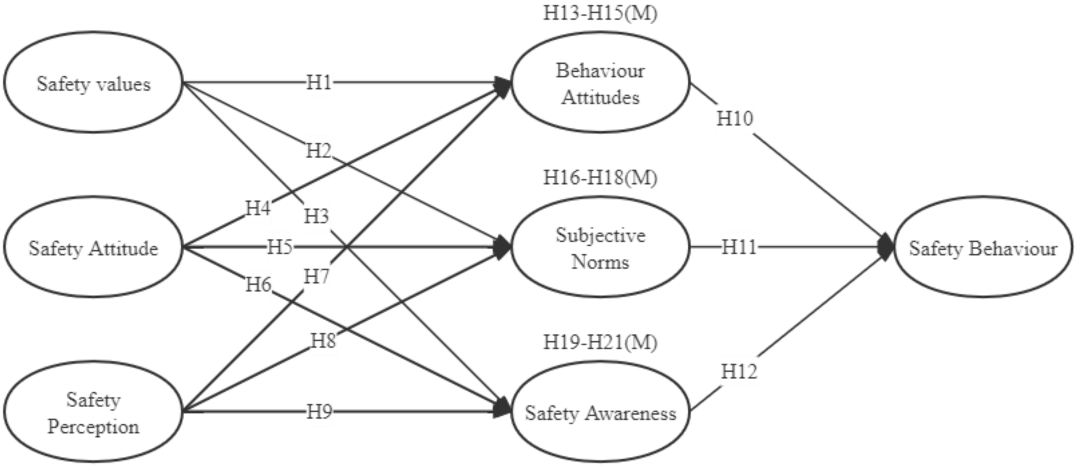

Figure 1. The empirical framework of the study

RESEARCH METHOD

3.1 Data collection

This study employed a stratified random sampling method to ensure the representativeness and comprehensiveness of the sample. The target population consisted of individuals engaged in experimental work in university chemistry laboratories in China, including undergraduate students, graduate students, and technical support staff. These groups were selected based on their direct involvement in laboratory operations and their active participation in safety behaviors, making them the primary subjects impacted by laboratory safety culture. Over a six-week survey period, a total of 499 valid questionnaires were collected. The sample size was determined through rigorous statistical calculations to meet the requirements of robust data analysis and ensure reliable results.

Data collection was primarily conducted through online questionnaires, supplemented by offline efforts. Offline data collection involved distributing surveys through laboratory managers in chemistry laboratories across multiple universities, aiming to capture safety behaviors and cultural influences within real-world laboratory settings. For online data collection, surveys were distributed via major digital platforms in China, such as WeChat and email, to enhance the diversity and representativeness of the sample. The questionnaire design underwent a pilot study to ensure clarity and the reliability of the questions. Reliability and validity analyses were conducted to confirm the scientific rigor and applicability of the measurement instruments. To encourage participation and improve response quality, small incentives were offered to respondents, such as opportunities to participate in laboratory safety-related learning activities or small commemorative gifts. Additionally, incomplete or low-quality responses were excluded during the data screening process to ensure the validity of the dataset.

By employing a stratified random sampling method and a combination of online and offline data collection approaches, this study ensured the diversity and representativeness of the sample. Furthermore, through meticulous questionnaire design, pilot testing, incentive mechanisms, and rigorous data screening, a reliable data foundation was established, providing robust empirical support for exploring the relationship between laboratory safety culture and safety behavior.

3.2 Measurement

This study employed a structured questionnaire as the measurement tool to investigate the influence of laboratory safety culture on safety behavior. The design of the measurement tool aligns with the research model and encompasses the following key constructs: safety values, safety attitudes, safety perceptions, safety awareness, subjective norms, behavioral attitudes, and laboratory safety behavior. Each construct was assessed using validated scales adapted from previous studies, ensuring the scientific rigor and reliability of the measurements.

The questionnaire used a 5-point Likert scale, ranging from 1 ("Strongly Disagree") to 5 ("Strongly Agree").Safety Values represented the second part of the questionnaire, and it was made up of four items adapted from Díaz-Cabrera et al. (2007). This section measured respondents' beliefs regarding the fundamental importance of safety in laboratory environments. Safety perception consisted of four items taken from Reader et al. (2015). Safety attitudes were assessed in the fourth section by three items adapted from Fung (2024), and these items emphasized nurturing of proactive attitudes Subjective Norms were measured with three items adapted from Manning (2009). This section examined the influence of institutional norms and peer expectations, such as the statement. Safety Awareness, consisted of four items from Wang et al. (2023) and assessed respondents' knowledge of and compliance with safety protocols. Behavioral attitudes were measured in the seventh section with three items adapted from Wang et al. (2023) and Zhao et al. (2021). The current section has measured participants' willingness to engage themselves in safety practices. Finally, Safety Behavior comprised the eighth section with two items adapted from Meng et al. (2019).

In ensuring the reliability and validity of the questionnaire, a pilot test involving 30 respondents was conducted. Feedback from the pilot study was used to refine the questionnaire for clarity and coherence. Reliability analysis confirmed that the internal consistency was strong, with Cronbach's alpha values for all constructs exceeding 0.7.

This stringent design and data collection process ascertained the robustness of the instrument and provided a solid base for subsequent data analysis.

3.3 Data analysis

The reliability validity of the questionnaire was initially examined by pretesting, then descriptive statistical analysis, reliability validity analysis, and structural equation model were used to process the data.A pre-test was conducted in the present study with 30 participants who had experience in university chemistry laboratories for perusal of the survey items regarding safety values, safety perception, safety attitudes, subjective norms, safety awareness, and behavioral attitudes and safety behavior in terms of their clarity, reliability, and validity. The pre-test phase is quite important in refining the survey instrument and aligning it with the theoretical constructs on which the research study has been based. These findings from this exploratory study prove the internal consistency of each construct since the Cronbach's alpha value is > 0.70 for all of them, depicting high reliability. Furthermore, feedback during the pre-test proved useful in highlighting item sets that were ambiguous and unclear. Some minor changes involving the use of less technical terminologies and resolving ambiguities were integrated into improving the understanding of the items in the questionnaire. These refinements provided a solid base for the main data collection and subsequent statistical analysis.

RESULTS

4.1 Description of the statistical analysis

A total of 499 valid questionnaires were collected for this study, with incomplete or non-compliant responses excluded to ensure data integrity. The demographic composition of the respondents, detailed in Table 1, reflects diverse backgrounds relevant to the research focus, providing a solid basis for analyzing safety culture and behavior in university chemistry laboratories.The gender distribution was relatively balanced, with 54.5% male respondents (n = 272) and 45.5% female respondents (n = 227), ensuring adequate representation of both perspectives. In terms of age, younger individuals predominated, with 38.7% aged 25 or below (n = 193) and 33.1% aged 25–30 (n = 165). Respondents aged 30–35 accounted for 17.2% (n = 86), while those over 35 formed the smallest group, at 11.0% (n = 55). This reflects the involvement of early-career researchers and students in chemistry laboratories.Educational backgrounds were also varied, with undergraduates comprising the largest group (48.5%, n = 242), followed by master's students (26.7%, n = 133) and doctoral students (24.8%, n = 124). This distribution highlights the sample's inclusion of individuals with foundational to advanced knowledge of laboratory practices and safety protocols, reinforcing its suitability for studying safety culture and behavior in academic chemistry laboratories.

Table 1 Sample Information

Information and options		Frequency	Percent
Gender	Male	272	54.5
	Female	227	45.5
Age	25 and below	193	38.7
	25-30	165	33.1
	30-35	86	17.2
	35 and above.	55	11.0
Education Level	Junior College Students	124	24.8
	Undergraduate	242	48.5

	Graduate	133	26.7

4.1 Reliability Test

Table 2 below show that all the constructs measured in this study have internal consistencies as indicated by their Cronbach's alpha values. Cronbach's Alpha is a widely accepted criterion for the reliability of a scale expressing the degree to which the items within a construct will be interrelated and conform to a common factor. In general, a threshold of 0.7 is considered acceptable for reliability, and higher values represent stronger internal consistency. According to Wang et al. (2023), in this study, safety perception had the highest reliability, with a Cronbach's alpha value of 0.859, confirming the strong internal coherence of the items designed to measure respondents' awareness and understanding of laboratory safety. In a similar vein, safety values had a Cronbach's alpha of 0.846, indicating excellent reliability in assessing the perceived importance of safety principles in laboratory settings. Safety awareness, too, was a very reliable construct, with the Cronbach's alpha of 0.842, signifying a high degree of consistency among items that measured the readiness of respondents to comply with safety measures. The other constructs, such as safety attitude ($\alpha = 0.799$), subjective norms ($\alpha = 0.785$), and attitude toward behavior ($\alpha = 0.788$), also attained a reliability well over the minimum acceptable threshold; thus, the respective sets of items are reliable in measuring participants' attitudes and perceptions toward laboratory safety practices. Finally, safety behavior had a Cronbach's alpha of 0.750, slightly lower but still above the threshold for acceptability and internal consistency for items assessing observed safety behavior in laboratory settings.

Table 2 Reliability Statistics

Study variables	**Number of questions**	**Cronbach's α**
Perceived ease of use of safety values	4	0.846
Perceived ease of use of safety perception	4	0.859
Perceived ease of use of safety attitudes	3	0.799
Perceived ease of use of subjective norms	3	0.785
Perceived ease of use of safety awareness	4	0.842
Perceived ease of use of behaviour attitudes	3	0.788
Perceived ease of use of safety behaviour	2	0.750

4.2 Validity analysis

The validity analysis, as shown in Table 3, assesses the suitability of the data for factor analysis using the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity. The KMO value of 0.889 exceeds the generally accepted threshold of 0.7, indicating that the sample data are appropriate for factor analysis. The KMO statistic measures the degree of intercorrelation among variables, with higher values suggesting that the variables are sufficiently compact to justify factor extraction. In this study, the obtained KMO value confirms that the dataset meets the necessary conditions for conducting reliable factor analysis, thereby strengthening the robustness of the subsequent analysis.In addition, Bartlett's Test of Sphericity was conducted to verify whether the correlation matrix significantly deviates from an identity matrix, where all variables would otherwise be uncorrelated. The test produced a highly significant result, with an approximate chi-square value of 4885.360, degrees of freedom (df) of 253, and a significance level of 0.000. This significant outcome ($p < 0.05$) confirms that there are sufficient interrelationships among the variables, further validating the dataset's appropriateness for factor analysis. The presence of strong correlations supports the assumption required for factor extraction and structure detection.

Table 3 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.889
Bartlett's Test of Sphericity	Approx. Chi-Square	4885.360
	df	253
	Sig.	0.000

4.3 Measurement model

Figure 2 illustrates a measurement model within the confirmatory factor analysis framework.

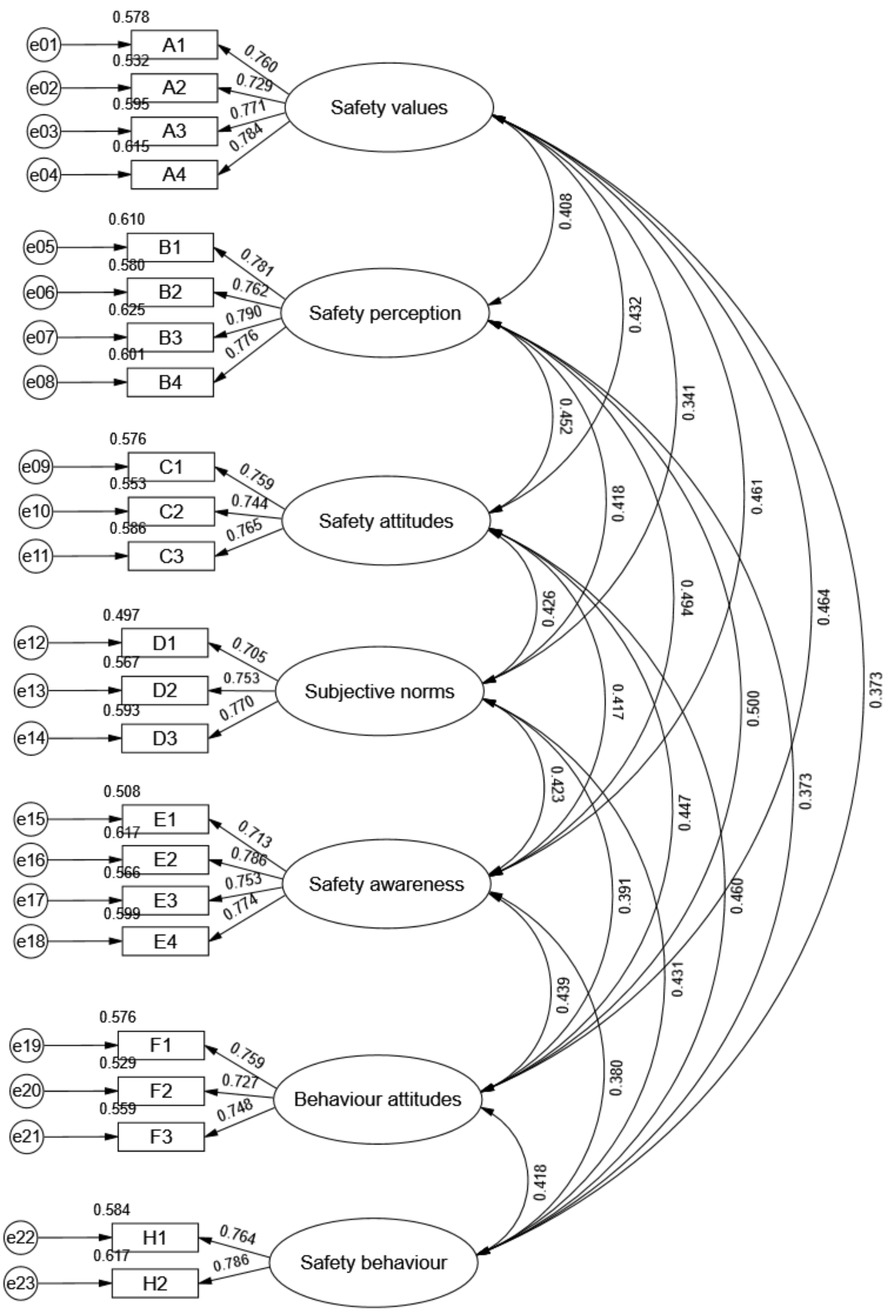

Figure 2 Measurement model diagram

The measurement model fit metrics presented in Table 4 demonstrate an excellent fit between the proposed model and the observed data, as evidenced by the key fit indices. The chi-square to degrees of freedom ratio (χ^2/df)

is reported as 1.195, which is well below the commonly accepted threshold of 3. This result indicates an appropriate balance between model parsimony and its ability to explain the data structure, suggesting that the hypothesized model accurately represents the relationships among the observed variables.The Root Mean Square Error of Approximation (RMSEA), which evaluates the discrepancy between the proposed model and the population covariance matrix, is 0.020. This value falls significantly below the benchmark of 0.08, confirming a minimal approximation error and a close fit of the model to the observed data. The low RMSEA value underscores the model's ability to capture the underlying data structure with minimal residual variance.Further fit indices provide additional evidence of the model's robustness. The Goodness-of-Fit Index (GFI) and the Adjusted Goodness-of-Fit Index (AGFI), which measure the extent to which the estimated population covariance matrix explains the observed variance, are 0.958 and 0.945, respectively. Both values exceed the established benchmark of 0.9, validating the adequacy of the model in representing the empirical data.The Normed Fit Index (NFI), Tucker-Lewis Index (TLI), and Comparative Fit Index (CFI), which evaluate the relative improvement of the proposed model over a baseline null model, recorded values of 0.950, 0.990, and 0.991, respectively. These values surpass the criterion of 0.9, indicating that the proposed model achieves a superior fit and exhibits excellent construct validity.

Table **Error! No text of specified style in document.** Measure model fit metrics

Fit index	χ2/df	RMSEA	GFI	AGFI	NFI	TLI	CFI
Reference standards	<3	<0.08	>0.9	>0.9	>0.9	>0.9	>0.9
Result	1.195	0.020	0.958	0.945	0.950	0.990	0.991

The results of the CFA from Table 5 show that all latent variables included in this study have strong convergent validity. Convergent validity refers to the degree to which multiple indicators of a construct relate, and three key metrics include: factor loadings, composite reliability, and variance extracted. The levels for all estimated factor loadings, measuring a specific level for each single observed indicator or every observed variance together as representatives of their corresponding latent variables, range from 0.705 to 0.786, all above the cut-off level generally considered to be more than 0.70. These high factor loadings mean that each indicator correlates highly with its respective construct and support the robustness of the measurement model. The CR values, representing the internal consistency of each latent variable, range from 0.751 to 0.859, above the threshold of 0.70 recommended. These results confirm that the set of indicators for each construct jointly and reliably measure their respective constructs, hence a high level of internal consistency among the variables. Also, the AVE values for all the constructs fall within the range of 0.552 to 0.604, hence above the threshold of 0.50. An AVE of more than 0.50 means that more than half of the variance of the observed indicators can be explained by the underlying latent construct rather than by measurement error. These results confirm that each construct has a high level of variance explained by its respective indicators, further reinforcing the convergent validity of the measurement model.

Table 5 Convergence Validity

Latent variables	Observation indicators	Factor loading	CR	AVE
Perceived ease of use of safety values	A1	0.760	0.846	0.580
	A2	0.729		
	A3	0.771		
	A4	0.784		
Perceived ease of use of safety perception	B1	0.781	0.859	0.604
	B2	0.762		

	B3	0.790		
	B4	0.776		
Perceived ease of use of safety attitudes	C1	0.759	0.800	0.572
	C2	0.744		
	C3	0.765		
Perceived ease of use of subjective norms	D1	0.705	0.787	0.552
	D2	0.753		
	D3	0.770		
Perceived ease of use of safety awareness	E1	0.713	0.843	0.573
	E2	0.786		
	E3	0.753		
	E4	0.774		
Perceived ease of use of behaviour attitudes	F1	0.759	0.789	0.555
	F2	0.727		
	F3	0.748		
Perceived ease of use of safety behaviour	H1	0.764	0.751	0.601
	H2	0.786		

In the interest of discriminant validity, the results of Table 6 confirm the suitability of this measurement model to distinguish among the latent variables. In particular, discriminant validity involves the extent to which each construct is conceptually distinct and measures a different unique aspect of the theoretical framework. This is checked through the Fornell-Larcker criterion, where the square root of each construct's AVE (presented along the diagonal) is compared against the inter-construct correlations expressed by the off-diagonal values. The square root of AVE for all constructs exceeds the corresponding inter-construct correlations, hence satisfying that each construct relates more strongly to its own observed indicators than to any other latent variable. This satisfies the Fornell-Larcker criterion and indicates that the latent variables maintain clear separability within the measurement model (Rönkkö & Cho, 2020).The inter-construct correlations range from 0.341 to 0.500, reflecting moderate relationships between constructs while maintaining distinctiveness. For example, the correlation between perceived ease of use of safety values and safety perception is 0.408, which is smaller than the square root of AVE for the two respective constructs (0.762 and 0.777 respectively). In a similar vein, safety attitudes show a square root of AVE of 0.756, higher than its highest inter-construct correlation of 0.452, and thus again confirm its discriminant validity. Other constructs, like subjective norms, with an AVE square root of 0.743, and safety behavior, with an AVE square root of 0.775, are also well distinguishable from the other variables because their AVE square roots always outperform the highest correlations with related constructs. These results establish that each latent variable is distinct and reliably measures a specific component of the theoretical model.

Table 6 Discriminant validity test

Latent variables	A	B	C	D	E	F	H
Perceived ease of use of safety values	**0.762**						
Perceived ease of use of safety perception	0.408	**0.777**					

Perceived ease of use of safety attitudes	0.432	0.452	**0.756**				
Perceived ease of use of subjective norms	0.341	0.418	0.426	**0.743**			
Perceived ease of use of safety awareness	0.461	0.494	0.417	0.423	**0.757**		
Perceived ease of use of behaviour attitudes	0.464	0.500	0.447	0.391	0.439	**0.745**	
Perceived ease of use of safety behaviour	0.373	0.373	0.460	0.431	0.380	0.418	**0.775**

Note: The diagonal is the square root of the corresponding dimension AVE.

A:Perceived ease of use of safety values; B: Perceived ease of use of safety perception; C: Perceived ease of use of safety attitudes; D: Perceived ease of use of subjective norms; E: Perceived ease of use of safety awareness; F: Perceived ease of use of behaviour attitudes; H: Perceived ease of use of safety behaviour.

4.4 Structural equation model

Figure 3 illustrates the structural equation model and path analysis diagram.

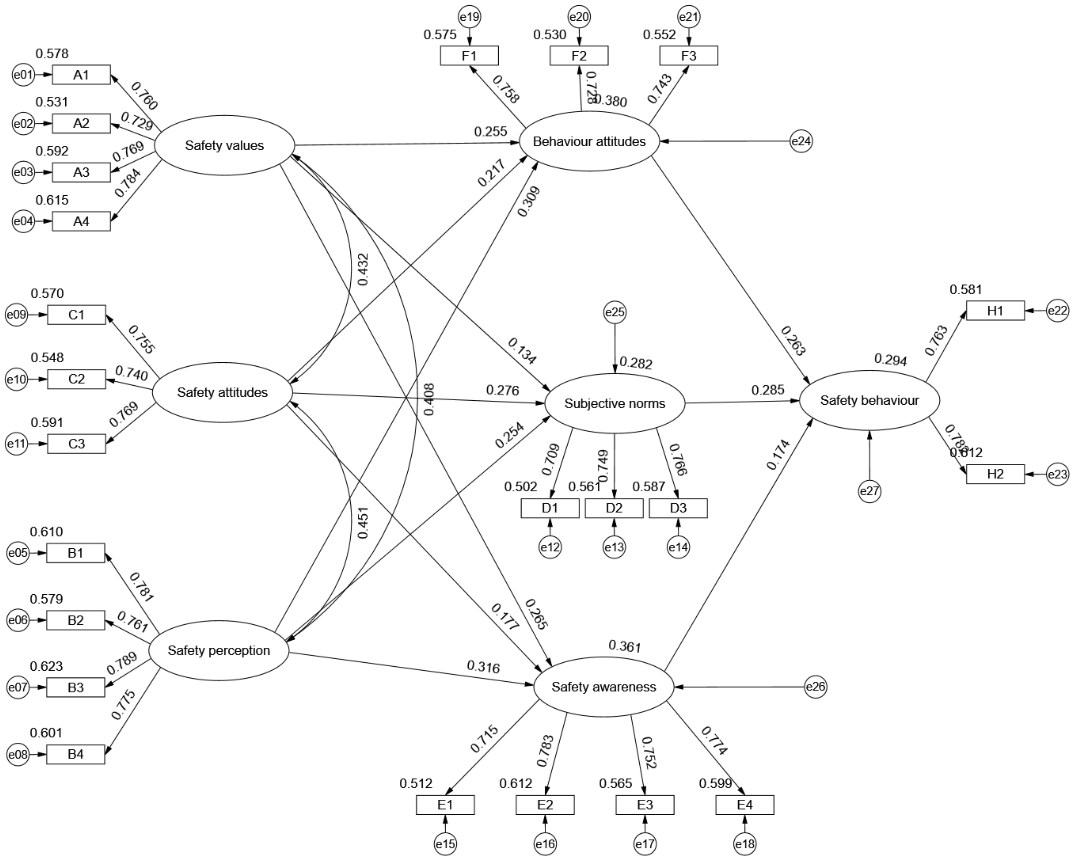

Figure *3* Structural equation model

Table 7 shows an excellent fit between the hypothesized model and the observed data, thus confirming the adequacy of the hypothesized model in explaining the relationships among the latent constructs. The χ^2/df is 1.305, which is way below the generally accepted threshold of 3. This is an indication of a very strong balance between the explanatory power and parsimony of the model, thereby suggesting that the model is well-specified and does not overfit the data. The Root Mean Square Error of Approximation (RMSEA), one of the important indicators of approximate fit, was 0.025, far below the threshold of 0.08. This low value of RMSEA reflects minimal residuals between the observed and predicted covariance matrices, thus providing strong evidence of the model's close fit to the underlying data structure. Other fit indices further validate the robustness of the structural model. The GFI was 0.954, while the AGFI was 0.940; both are above the recommended threshold of 0.9. These values confirm that the model is relatively explanatory to a significant amount of the variation in data, besides allowing for model complexity. Again, incremental fit indices will give the comparative model fits in relation to either the null or baseline model: The Normed Fit Index stands at 0.944, and equally good, the Tucker-Lewis Index and Comparative Fit Index reach 0.984 and 0.986, respectively. All of these indices are also above the cutoff criterion threshold of 0.9, indicating that the hypothesized relationships among latent variables are well supported by the data. High incremental fit indices further support the appropriateness of the model over a baseline model in a significant way, therefore giving further evidence for robustness and theoretical validity.

Table 7 Model fit metrics

Fit index	χ2/df	RMSEA	GFI	AGFI	NFI	TLI	CFI
Reference standards	<3	<0.08	>0.9	>0.9	>0.9	>0.9	>0.9
Result	1.305	0.025	0.954	0.940	0.944	0.984	0.986

The direct path analysis results, as shown in Table 8, provide insights into the relationships among the latent variables in the structural model. The unstandardized path coefficients (Estimate) represent the direct effects between constructs, while the standardized coefficients (β) indicate the strength of these effects on a standardized scale. The significance of each path is confirmed by the Critical Ratio (C.R.), with values exceeding the threshold of 1.96, and P-values indicating statistical significance at various confidence levels.The results show that all hypothesized paths are statistically significant. For example, safety values significantly influence behavior attitudes (H1: $\beta = 0.255$, C.R. = 4.405, $p < 0.001$) and subjective norms (H2: $\beta = 0.134$, C.R. = 2.262, $p = 0.024$), while safety attitudes also strongly affect behavior attitudes (H4: $\beta = 0.309$, C.R. = 5.246, $p < 0.001$) and subjective norms (H5: $\beta = 0.254$, C.R. = 4.154, $p < 0.001$).Additionally, behavior attitudes, subjective norms, and safety awareness exhibit significant positive effects on safety behavior. For instance, behavior attitudes have a standardized coefficient of 0.263 (C.R. = 4.180, $p < 0.001$), while subjective norms and safety awareness yield standardized effects of 0.285 and 0.174, respectively.

Table 8 Direct path effects

Hypothesis	Path	Estimate	β	S.E.	C.R.	P	Results
H1	A→F	0.278	0.255	0.063	4.405	***	Supported
H2	A→D	0.132	0.134	0.058	2.262	0.024	Supported
H3	A→E	0.254	0.265	0.054	4.693	***	Supported
H4	C→F	0.323	0.309	0.062	5.246	***	Supported
H5	C→D	0.239	0.254	0.058	4.154	***	Supported
H6	C→E	0.291	0.316	0.053	5.502	***	Supported
H7	B→F	0.245	0.217	0.069	3.559	***	Supported
H8	B→D	0.281	0.276	0.066	4.240	***	Supported
H9	B→E	0.175	0.177	0.058	3.016	0.003	Supported

H10	F→H	0.245	0.263	0.059	4.180	***	Supported
H11	D→H	0.294	0.285	0.064	4.591	***	Supported
H12	E→H	0.184	0.174	0.063	2.938	0.003	Supported

Note: A:Perceived ease of use of safety values; B: Perceived ease of use of safety perception; C: Perceived ease of use of safety attitudes; D: Perceived ease of use of subjective norms; E: Perceived ease of use of safety awareness; F: Perceived ease of use of behaviour attitudes; H: Perceived ease of use of safety behaviour.
***: $p<0.001$

The mediation analysis results presented in Table 9 examine the indirect effects of safety values, safety attitudes, and safety perceptions on safety behavior through mediators such as behavior attitudes, subjective norms, and safety awareness. The effect value quantifies the magnitude of the indirect effects, showing how much the mediators contribute to the relationship between the independent and dependent variables. For instance, the mediation path A → F → H (H13) has an effect value of 0.068, indicating that behavior attitudes partially mediate the relationship between safety values and safety behavior. The standard error (S.E.) represents the variability in these estimates, providing insight into the reliability of the indirect effects.The Bias-Corrected 95% Confidence Interval (CI) is used to assess the statistical significance of the indirect effects. If the CI does not include zero, the mediation effect is considered significant. For example, the CI for H13 (A → F → H) ranges from 0.018 to 0.131, confirming a significant mediation effect. However, for unsupported hypotheses such as H16 (A → D → H) and H20 (C → E → H), the CI includes zero, indicating that the indirect effects through subjective norms and safety awareness, respectively, are not statistically significant.The results confirm several significant mediation pathways. Behavior attitudes serve as a consistent mediator in the relationships between safety values (H13: 0.068), safety attitudes (H14: 0.060), and safety perceptions (H15: 0.079) with safety behavior. Similarly, subjective norms significantly mediate the effects of safety attitudes (H17: 0.083) and safety perceptions (H18: 0.070), while safety awareness acts as a mediator in the paths from safety values (H19: 0.047) and safety perceptions (H21: 0.053) to safety behavior.

Table 9 Indirect effect bootstrap test

Hypothesis	Mediation path	Effect value	SE	Bias-Corrected 95%CI		Results
H13	A→F→H	0.068	0.030	0.018	0.131	Supported
H14	C→F→H	0.060	0.033	0.009	0.136	Supported
H15	B→F→H	0.079	0.031	0.025	0.146	Supported
H16	A→D→H	0.039	0.028	-0.009	0.103	Unsupported
H17	C→D→H	0.083	0.041	0.017	0.184	Supported
H18	B→D→H	0.070	0.029	0.021	0.130	Supported
H19	A→E→H	0.047	0.025	0.002	0.102	Supported
H20	C→E→H	0.032	0.024	-0.001	0.089	Unsupported
H21	B→E→H	0.053	0.028	0.002	0.114	Supported

Note: A:Perceived ease of use of safety values; B: Perceived ease of use of safety perception; C: Perceived ease of use of safety attitudes; D: Perceived ease of use of subjective norms; E: Perceived ease of use of safety awareness; F: Perceived ease of use of behaviour attitudes; H: Perceived ease of use of safety behaviour.

The total effects presented in Table 10 provide a comprehensive overview of the combined direct and indirect impacts of safety values, safety attitudes, and safety perceptions on various mediators and safety behavior. Total effects integrate all pathways, both direct and mediated, offering a holistic view of the influence each variable exerts on others within the model.For example, the total effect of safety values (A) on behavior attitudes (F) is 0.278, with a confidence interval (CI) of [0.116, 0.428], confirming a significant influence. Similarly, safety perceptions (B) exhibit the strongest total effect on behavior attitudes (F) at 0.323 (CI: [0.172, 0.500]), emphasizing the central role of perceptions in shaping attitudes toward safe practices.

The relationships between safety constructs and subjective norms (D) also reveal significant effects. Safety attitudes (C) show the strongest total effect on subjective norms (0.281, CI: [0.085, 0.472]), indicating that attitudes have a substantial impact on normative beliefs. Safety perceptions (B) also influence subjective norms with a total effect of 0.239 (CI: [0.088, 0.401]), suggesting that perceptions play a significant role in shaping social pressures regarding safety. In contrast, safety values (A) have a smaller and non-significant total effect on subjective norms (0.132, CI: [-0.032, 0.300]), indicating that values alone may not directly influence norms without intermediary factors.The total effects on safety behavior (H) underscore the pivotal roles of subjective norms (D), behavior attitudes (F), and safety awareness (E) as mediators. Subjective norms (D) exhibit the strongest total effect on safety behavior (0.294, CI: [0.127, 0.448]), followed by behavior attitudes (F) (0.245, CI: [0.100, 0.407]) and safety awareness (E) (0.184, CI: [0.008, 0.342]). Among the primary predictors, safety perceptions (B) show the most substantial total effect on safety behavior (0.203, CI: [0.120, 0.286]), surpassing both safety attitudes (C: 0.175, CI: [0.078, 0.303]) and safety values (A: 0.154, CI: [0.066, 0.247]).

Table 10 Total Effects

Effect path	Effect size	SE	Bias-Corrected 95%CI	
A→D	0.132	0.084	-0.032	0.300
C→D	0.281	0.097	0.085	0.472
B→D	0.239	0.076	0.088	0.401
A→F	0.278	0.080	0.116	0.428
C→F	0.245	0.094	0.065	0.421
B→F	0.323	0.085	0.172	0.500
A→E	0.254	0.073	0.108	0.400
C→E	0.175	0.083	0.012	0.343
B→E	0.291	0.069	0.165	0.426
A→H	0.154	0.044	0.066	0.247
C→H	0.175	0.056	0.078	0.303
B→H	0.203	0.041	0.120	0.286
D→H	0.294	0.084	0.127	0.448
F→H	0.245	0.078	0.100	0.407
E→H	0.184	0.084	0.008	0.342

Note: A:Perceived ease of use of safety values; B: Perceived ease of use of safety perception; C: Perceived ease of use of safety attitudes; D: Perceived ease of use of subjective norms; E: Perceived ease of use of safety awareness; F: Perceived ease of use of behaviour attitudes; H: Perceived ease of use of safety behaviour.

DISCUSSION

5.1 Theoretical Implications

This study confirms that safety values significantly influence safety attitudes (H1), reinforcing the theoretical premise that individuals' underlying beliefs and motivations about safety shape their attitudes toward adhering to safety protocols. This finding aligns with existing safety culture theories, such as those by Ramesh and Norazahar (2024), who emphasize the foundational role of safety values in fostering commitment to safe practices. However, our research advances this perspective by demonstrating how cognitive mechanisms, such as behavioral attitudes and safety awareness, mediate the relationship between safety values and behavior. This nuanced understanding extends beyond prior models, offering a more integrated view of safety culture.

Safety attitudes, as hypothesized (H3), positively influence safety behavior. According to Ajzen's Theory of Planned Behavior, attitudes are critical antecedents to behavior. The significant direct effect of safety attitudes on safety behaviors highlights the importance of nurturing positive safety attitudes, as they translate directly into safer actions, reducing accidents in laboratory settings. While Abdullah and Abd Aziz (2020) emphasize the direct role of safety knowledge and motivation, our findings show that attitudes act as a crucial cognitive filter, mediating the effect of safety values on behavior. This expands theoretical insights by underscoring attitudes as both an outcome of values and a driver of safety behavior.

An important theoretical contribution of this study lies in the nonsignificant result for H2, which hypothesized that safety perceptions directly impact safety attitudes. This finding challenges traditional linear models, such as those proposed by Ayi and Hon (2018), which assume a direct relationship between perceptions and attitudes. Our results suggest that this link may be mediated by constructs like safety awareness or moderated by situational variables. This represents a departure from conventional theories and highlights the complexity of the relationships within safety culture, calling for refined models that capture these indirect effects. Future research could investigate additional mediating and moderating factors to fully understand the dynamics between perceptions and attitudes.

This study also tested the mediating effects of safety awareness, subjective norms, and behavioral attitudes in the relationship between safety culture and safety behavior. Significant mediation effects were found for safety awareness and behavioral attitudes, supporting several pathways (e.g., H13, H14, H15, H19, H20). These results indicate that safety culture influences behavior not only through direct effects but also via internal cognitive processes and external social factors. For instance, the mediation through behavioral attitudes (H13, H14) suggests that attitudes serve as a cognitive mechanism through which safety values and perceptions are internalized into behavior. This finding aligns with the work of Staehle et al. (2016), who emphasize the importance of addressing behavioral factors in enhancing safety culture. However, our study extends their work by highlighting the critical role of safety awareness as a mediator, as reflected in pathways such as H19 and H20.

In contrast, the mediating effects of subjective norms (H16, H17, H18) were not supported. This finding challenges the assumption, often emphasized in prior studies such as those by Abdullah and Abd Aziz (2020), that peer behavior or societal expectations strongly influence safety practices. Our results suggest that subjective norms may play a less significant role in laboratory settings, where personal attitudes and awareness appear to have a greater impact on safety behavior. This insight refines our understanding of the interplay between social pressures and individual cognitive factors, suggesting that the influence of subjective norms may be context-dependent.

Regarding safety awareness, its mediating role in H19, H20, and H21 underscores its critical importance in bridging the gap between safety values, attitudes, and behaviors. These findings resonate with the conclusions of Malla et al. (2024), who emphasize the role of risk awareness in fostering adherence to safety protocols. Our study validates and extends these insights by demonstrating that safety awareness not only enhances safe behavior but also strengthens the internalization of safety culture principles among laboratory personnel. This positions safety awareness as a cornerstone of effective safety management systems.

Overall, this study advances theoretical understandings of safety culture by challenging established models and introducing new insights into the complex interplay between safety values, attitudes, perceptions, and behaviors. Unlike traditional models that focus on direct effects, our findings highlight the importance of indirect pathways mediated by cognitive (e.g., attitudes, awareness) and social (e.g., norms) dimensions. This approach refines safety culture theories, emphasizing the integration of these elements into more comprehensive frameworks. Furthermore, the rejection of certain hypotheses, such as the direct effect of perceptions on attitudes, calls for a re-examination of linear assumptions and a focus on indirect relationships and situational moderators.

These findings not only enrich the literature but also provide actionable insights for improving safety management systems. By addressing psychological and social dimensions alongside technical safety measures, this study offers a robust framework for enhancing safety culture and behavior in laboratory settings. Future research should further explore the identified gaps and refine theoretical models to better capture the dynamics of safety culture and its influence on behavior.

5.2 Practical implications

This study provides insights that are particularly valuable and of great practical consequence to several stakeholders in the promotion of safety culture in university chemistry laboratories. The findings contribute to the development of better safety management strategies, improvement of safety education, and the development of a safety culture in academic institutions. The practical implications include several key groups: university administrators, laboratory managers, academic staff, students, and policy-makers.

It indicates that what needs to be created among university administrators is a strong safety culture from a formal policy perspective but also in terms of informal practices. In particular, it indicates the need for embedding the values of safety into the mission and objectives of the institution, putting into organizational culture written policies regarding safety. Direct influences of safety values on the behavioral attitude and safety awareness reveal that the administrator should make an effort to create such an environment where the value of safety is shared by all, and all the members of the academic community embrace and practice safety. Furthermore, the gap between safety values and actual safety behavior must be minimized through increasing awareness by focused education programs.

This study, therefore, gives clear recommendations on the role of behavioral attitude and safety awareness in shaping the laboratory safety behaviors, by the laboratory managers. Positive safety attitudes among the laboratory staff and students should, as such, be ensured upon by the laboratory manager. This can be achieved by making the safety training programs promote in the trainees a better appreciation of the role of safety attitude in safer behavior, in addition to the technical knowledge. The continuous safety education, risk assessment, and drills are shown in the study to develop better safety awareness. Managers can positively involve laboratory staff in such activities in order to increase their awareness of safety risks and good practices, thus improving the safety performance.

The practical recommendations are also put forward for academic staff involved in laboratory teaching. The findings have pointed out that perceptions of safety and subjective norms play a vital role in students' safety behavior. The faculty members should make active manifestations of the importance of safety practices and encourage students to internalize values of safety practices. Faculty members can create a safety culture by modeling appropriate behaviors and consistently communicating the value of safety, which in turn shapes students' attitudes and compliance with safety protocols. The rejection of the direct influence of safety perceptions on subjective norms in this study seems to suggest that, while instructors' behaviors may make students influence their subjective norm, other factors, like peer influence or institutional policy, are needed to provide a safety culture among the students.

This research means that, for students, internalization of safety values and development of positive attitude toward safety behavior are decisive. Students should be motivated on the importance of actively engaging in safety training and to take responsibility for their individual safety behavior. They need to understand the wider academic institution safety culture, including expectations of students by both their peers and instructors. In addition, it is important that students recognize how their individual safety behavior contributes to overall laboratory environment. The present study indicates that the development of appropriate safety values and attitudes in the students will provide the key to the reduction of safety incidents and to safer learning in the future.

The beneficiaries of these findings are also policy-makers. The study stresses that academic institutions, particularly laboratory policies, should be supportive of the culture of safety. The study indicated that while formal organizational practices and policies were essential, they had to be supplemented by an enabling environment in which safety values are continuously promoted. This may involve developing policies that make for periodic training sessions in safety matters, that appropriate risk assessments are conducted, and the use of safety equipment is put into practice. For example, the design of safety regulations by policy-makers should be informed by broadened perspectives of social and psychological influences, such as subjective norms and behavioral attitude. Furthermore, policy-makers are supposed to ensure that safety culture surpasses mere compliance and encompasses proactive participation from all the stakeholders.

Lastly, these findings have their implications in the design of safety training programs and in curriculum development at academic institutions. With the significant role of safety awareness, subjective norms, and attitude toward behavior, training should not be strictly technical but also psychological-social. Training modules should look to cover how personal attitude, meta-cognition about one's attitude, and that of others influence safety behaviors, students', and staff members' contribution to the building up of a safety culture. Moreover, the inclusion of industrial-based case studies and safety simulation in the curriculum will contribute to better effectiveness of the safety training to be more interesting and applicable by participants.

The practical implications of this study encompass different stakeholders who have distinct interest in university chemistry laboratories such as administrators, laboratory managers, academic staff, students, and policy-makers. Hence, this provides a holistic framework covering the psychological and social dimensions of safety, in addition to the technical aspects of improvement in safety culture in academia. Stakeholders should foster values about safety, enhance awareness of safety issues, and promote positive safety attitudes to minimize risks that compromise the safety and productivity of the learning environment. The findings of this study also indicate that safety management needs an integrated approach, combining formal policies with informal cultural factors to develop a sustainable safety culture.

CONCLUSION

Based on the findings and analysis, therefore, the subsequent conclusion synthesizes the insights on relationships involving safety culture constructs with respect to the behavior regarding safety, mainly in the laboratories of a university setting.

This study tries to find the influence of the elements of safety culture like values, attitudes, perceptions, subjective norms, and safety awareness on the safety behavior of the employees in the university laboratories. Using the SEM technique, along with the mediation analysis, helped this research establish empirical evidence to confirm the theoretical framework presented in this study.

These findings confirm that there are statistically significant direct and indirect relationships among the constructs of safety values, safety perceptions, safety attitudes, and safety behavior. Specifically, safety perceptions proved to have the highest total effect on behavior attitudes, highlighting the pivotal position of individual subjective perceptions in shaping attitudes towards safety practices. The indirect paths, through the mediators of behavioral attitudes, subjective norms, and safety awareness, were also proved to be significant, thus proving the complex pathways through which safety culture impacts safety behavior. These results underline how individual and organizational factors are of key importance in fostering a safe laboratory environment.

The study also enumerated a number of areas for further research. Whereas some hypothesized relationships were supported, others were not, including the indirect effects of safety values on behavior through subjective norms, which again suggested that the influence of external social factors was in need of further exploration. The nonsignificant paths suggest that not all the dimensions of safety culture bear equal importance, therefore opening avenues for more subtle explorations of their interaction in various contexts or populations.

This research extends existing literature on safety culture by developing an overall model that puts together various safety-related constructs with their mediating effects. This research contributes to this area of study by shedding more light on how all elements of safety culture interact in setting the individual safety behavior that fits best within high-risk settings, such as those involving laboratory work. The findings have important implications for university administrators and safety officers and suggest that safety culture interventions should be targeted not only at improving individual safety behaviors but also at improving the overarching safety culture in academic environments.

Therefore, the findings from this study will enrich the theoretical framework on safety behavior and provide a further guiding function for improving the current safety practices in university laboratories. It highlights how far safety attitudes, subjective norms, and safety awareness serve as significant mediators of safety management, underlining that safety management requires consideration of both individual attitude and organizational culture. Additional research is needed regarding the factors that influence how strong or in which direction these associations exist, as this can help in building better safety programs within the academic environment.

Appendix 1. Measurement

Construct	Original Items	Source
safety values	1.Safety is regarded as the most valuable asset of the laboratory 2.Laboratory operations are related to the life 3.health and well-being of laboratory personnel 4.Laboratory safety behaviour is a need for self-actualization	Díaz-Cabrera et al. (2007); Sakalli and Arikan (2024)
Safety perceptions	1. Laboratory safety is everyone's responsibility, always vigilant 2. Laboratory safety experience should be widely publicized and exchanged 3. Risk control and safety systems thinking learning all the time 4. Good psychological characteristics of laboratory personnel is the guarantee of safe production	Reader et al. (2015)
Safety attitudes	1. Seriously implement the policy of 'safety first, prevention first'. 2. A questioning attitude should be fostered in experiments 3. Examples of safe behaviour should be supported and promoted	Fung (2024)
Subjective norms	1.Familiar with the workflow of the laboratory 2.Be able to consciously grasp the work emergency plan and method 3.Be able to work with protective measures	Manning (2009)
Safety awareness	1.I can consciously carry out the safety confirmation before experiment operation 2.I can consciously abide by the rules and regulations of the laboratory	Wang et al. (2023)

	3.I have a strong sense of self-protection for safety 4.I always check the signatures of my safety responsibilities.	
Behaviour attitudes	1. Able to conscientiously participate in safety education and oath 2. Violation of the work should be severely punished 3. Respect for leadership and solidarityMeng	Wang et al. (2023); Zhao et al. (2021)
Safety behaviour	1. If a safety hazard is identified, it should be reported at the first opportunity 2. Correctly implement safety procedures, wear protective clothing	Hayes et al. (1998); Meng et al. (2019)

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