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Optimizing Learning through Classroom Design: The Role of Physical Environmental Mediators

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The learning environment plays a pivotal role in shaping students' academic performance and overall well-being. In recent years, there has been growing recognition of the need to consider both physical and psychosocial elements in the design and management of classrooms to foster more effective teaching and learning. This study aims to evaluate the management of physical environmental factors and existing psychosocial aspects within classrooms, and to propose a model for creating conducive learning environments in schools, with physical environmental factors acting as a mediating variable. A total of 250 primary school students from ten schools across the East Coast of Peninsular Malaysia participated in this exploratory sequential mixed-method research. Instruments utilized included a lux meter, heat meter, sound level meter, measuring tape, and the *My Class Inventory* (MCI).The results indicated that all classrooms recorded lighting levels above 500 lux and complied with the temperature standard of not exceeding 32.5°C. However, most classrooms experienced noise levels above the recommended threshold of 60 dBA, making them less conducive to learning. Additionally, classroom space was found to be inadequate to support effective learning activities. The psychosocial levels among students were reported to be low to moderate. Based on the findings, the recommended standard values for a conducive classroom environment are as follows: lighting at a minimum of 500 lux, temperature not exceeding 32.5°C, noise levels below 35 dBA, classroom space ranging between 1.39 m^2 and 2.72 m^2 per student, and a minimum psychosocial level score of 3.62. The study further revealed that several psychosocial aspects significantly influenced learning outcomes ($p < 0.001$), with the exception of competition and friction, which had a negative impact on student performance. Notably, friction and cohesion were found to be significant mediators in enhancing learning outcomes (effect = 1.6397, BootSE = 0.2873; effect = 0.2356, BootSE = 0.0333, respectively).This study contributes to the existing body of literature by employing an exploratory sequential mixed-methods approach to explore how physical environmental factors mediate the relationship between psychosocial variables and learning outcomes. The findings offer practical recommendations for enhancing the teaching and learning process and underscore the importance of integrating both physical and psychosocial considerations in classroom design and management.

Keywords: Classroom Management, Psychosocial, Noise, Lighting, Learning Outcome.

INTRODUCTION/ LITERATURE REVIEW

The classroom environment plays a crucial role in influencing students' learning processes (Graça et al., 2007; Kruger & Zannin, 2004). A high-quality and comfortable classroom is also essential in shaping students' emotions and attitudes toward their peers, the subjects being studied, and the overall education system (Zedan, 2010). Tableman (2004) identified four key aspects of a positive school environment: a friendly and conducive physical environment; a social environment that fosters communication and interaction; an effective environment that supports a sense of belonging and self-esteem; and an academic environment that encourages learning and personal fulfillment.

According to the Commonwealth Science Council Technical Publication (1983), it is not possible to objectively define the characteristics of a comfortable environment, as comfort is inherently subjective and individuals may respond to the same environment in different ways. The *Dewan Bahasa Melayu Thesaurus* (2005) defines comfort using a range of synonymous terms, including tranquility, spaciousness, relief, peace, and serenity. A comfortable learning environment has been shown to enhance learning effectiveness. In this context, classroom comfort refers to the creation of a setting that provides students with a conducive atmosphere for learning (*Kamus Dewan*, 2017). Lilia Halim (2009) noted that in Malaysia, many studies have primarily focused on students' perceptions of the classroom environment, while limited attention has been given to the relationship between the physical characteristics of classrooms and students' psychosocial aspects. This observation is supported by Mohd Hairy et al. (2012), who argue that research on the physical environment and psychosocial factors in Malaysian schools remains in its early stages. These studies also emphasize the urgent need for the Ministry of Education Malaysia (KPM) to implement programs for upgrading and rebuilding underperforming schools, as many existing facilities are unsafe, inadequate, or non-functional.

The psychosocial environment must align with the needs of both teachers and students. Research indicates that the smaller the gap between the actual classroom psychosocial environment and the desired one, the more positive the impact on learning outcomes (Fraser, 2012; Chang et al., 2010; Selamat et al., 2023). The measurement of physical factors will be affecting on students' level of comfort that compared with the standards used. Several acts and standards have been used such as the School Registration Ordinance 1950, Standards & Industrial Research Institute of Malaysia (SIRIM), American Conference of Governmental Industrial Hygienists (ACGIH) and American National Standards Institute (ANSI) for acoustic performance criteria, design requirements, and guidelines for schools. The standards provided need to follow the purpose of the learning process at school so that the appropriate level of student comfort can be achieved.

Therefore, this study aims to determine the physical level and existing psychosocial aspects in the classroom. This study also proposes a framework that shows the relationship between these two aspects, as well as their contribution to students and schools on teaching and learning in the classroom, and subsequently produces a standard in classroom. Specifically, the objectives are:

i) To explore classroom environmental conditions by assessing:

- Lighting levels based on the Standards and Industrial Research Institute of Malaysia (SIRIM, 2018),
- Thermal comfort according to the American Conference of Governmental Industrial Hygienists (ACGIH, 2017),
- Noise levels based on the American National Standards Institute (ANSI S12.60, 2002), and
- Spatial comfort in accordance with the School Registration Ordinance (Malaysia, 1950).

ii) To examine the relationships between psychosocial aspects (satisfaction, conflict, competitiveness, difficulty, cohesion, and student interest) and classroom environmental factors (space, noise, lighting, and temperature).

iii) To determine whether psychosocial aspects (satisfaction, conflict, competitiveness, difficulty and cohesion) significantly predict student learning outcomes.

iv) To analyze whether physical classroom environmental factors mediate the relationship between psychosocial aspects and learning outcomes.

METHODOLOGY

This study adopted a mixed-methods approach involving 250 students from the East Coast of Peninsular Malaysia. The sample was drawn from 10 primary schools, comprising a total of 20 classrooms. Participants were students aged 11 to 12 years, with a gender distribution of 70% female and 30% male, selected through a convenience sampling method. The primary aim was to identify physical environmental standards and assess both the physical and psychosocial aspects of classroom environments. Data collection incorporated the use of various instruments and student-administered questionnaires. Thermal conditions were measured using the Heat Stroke Meter E17810, which offers an accuracy range between 0°C and 50°C. Lighting levels were assessed with the Digital Lux Meter AS803 (version 6-AS803-0112-02). Thermal comfort was further evaluated using the Wet Bulb Globe Temperature (WBGT), calculated as a weighted average of three temperature components. For indoor environments, the formula $WBGT_i = 0.7\,WB + 0.3\,G$ was applied, while outdoor conditions used the formula $WBGT_o = 0.7\,WB + 0.2\,G + 0.1\,DB$. These values were compared against the standards set by the American Conference of Governmental Industrial

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Hygienists (ACGIH). Sound levels were measured using a sound level meter in accordance with specifications outlined by Harris (1979).

To assess the psychosocial classroom environment, the study employed the My Class Inventory (MCI), developed by Fraser and Fisher (1983), which evaluates key social dimensions influencing student experiences in the classroom.

RESULTS

To evaluate the internal consistency of the scales used in the study, Cronbach's alpha coefficients were calculated for each variable. The results indicate that the following constructs demonstrated acceptable reliability: Satisfaction

(α = .753), Student Interest (α = .814), Space (α = .846), Noise (α = .744), Lighting (α = .846), and Temperature (α = .744). In addition, several constructs exhibited excellent reliability: Conflict (α = .901), Competitiveness (α = .850), Difficulty (α = .895), and Cohesion (α = .912). Overall, the instrument demonstrated excellent internal consistency, with a total Cronbach's alpha of .945 across all 73 items.

Table 1: Reliability Analysis of Study Variables

	Cronbach's Alpha	Number of Items	Rating
Satisfaction	0.753	9	Acceptable
Conflict	0.901	8	Excellent
Competitive	0.85	7	Excellent
Difficulty	0.895	8	Excellent
Cohesion	0.912	6	Excellent
Student Interest	0.814	15	Acceptable
Space	0.846	5	Acceptable
Noise	0.744	5	Acceptable
Lighting	0.846	5	Acceptable
Temperature	0.744	5	Acceptable
Overall	0.945	73	Excellent

Lighting In Classroom Based on Standards & Industrial Research Institute of Malaysia, Sirim (2018)

The illuminance levels recorded across classrooms ranged from 391.77 lux to 966.18 lux. While most classrooms showed lighting levels above the minimum threshold of 500 lux, the data indicated that SK6 and SK10 did not meet this standard, as their readings fell below the recommended level. The highest mean illuminance was recorded in the SK1 classroom after the break, with a reading of 966.20 lux, followed by SK4 at 942.30 lux. In contrast, the SK6 classroom after the break recorded the lowest mean illuminance at 390.57 lux.

Observational findings suggest that architectural features—such as exterior corridors—may obstruct the entry of natural sunlight into some classrooms. Additionally, the geographic placement of certain schools on hilly terrain influences sunlight exposure. The sun's position between 8:00 a.m. and 10:00 a.m. affects lighting conditions in classrooms before the break, while maximum sunlight occurs between 11:00 a.m. and 1:00 p.m., corresponding with the after-break sessions.

Thermal Comfort in the Classroom Based on the American Conference of Governmental Industrial Hygienists (ACGIH)

The measurement of thermal comfort in classrooms encompasses parameters such as temperature, air humidity,

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radiant heat, and air movement. These parameters were averaged to calculate the Wet Bulb Globe Temperature for indoor (WBGTi) and outdoor (WBGTo) environments. For the purpose of this study, the WBGTi was used as the primary indicator of thermal comfort within the classroom setting. Most classrooms were equipped with three ceiling fans.

According to the American Conference of Governmental Industrial Hygienists (ACGIH), the recommended maximum WBGTi for classroom activities should not exceed 32.5 °C. All classrooms in this study complied with this standard, with WBGTi readings ranging between 25.2 °C and 27.9 °C. It was also observed that WBGTi values tended to be higher during after-break sessions compared to before-break sessions.

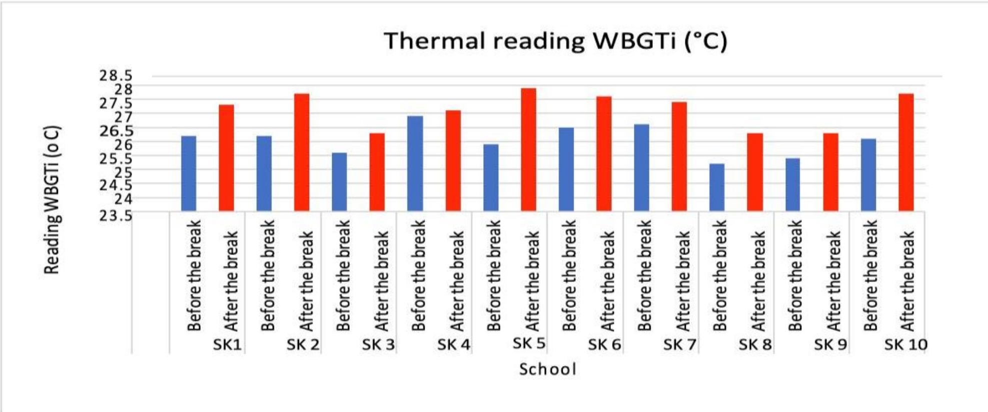

Figure 1. WBGTi readings (Wet Bulb Globe Temperature indoor) according to schools.

Based on the WBGTi measurements, most schools adhered to the thermal comfort standard set by the American Conference of Governmental Industrial Hygienists (ACGIH), which specifies a maximum allowable WBGTi of 32.5 °C. All classrooms recorded WBGTi values below this threshold, ranging from 25.2 °C to 27.9 °C. Although ambient classroom temperatures were relatively high, the presence of adequate air movement and humidity levels contributed to maintaining WBGTi readings within a comfortable range.

Noise Level in the Classroom Based on the American National Standards Institute (ANSI)

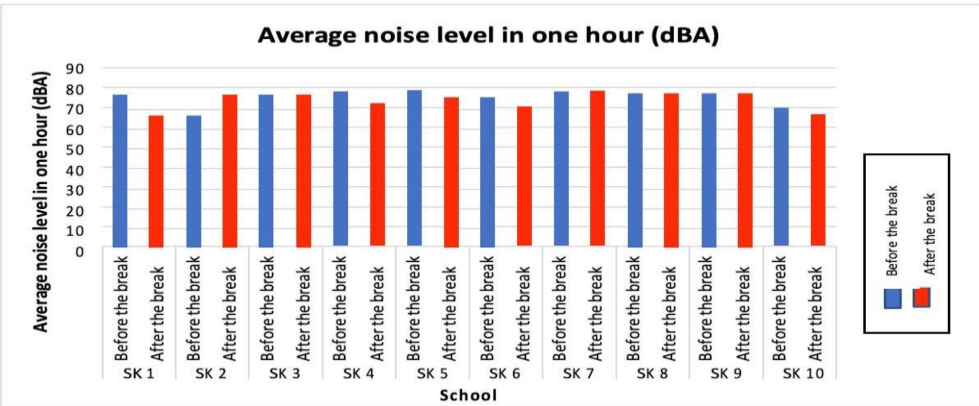

Figure 2. Average noise level for the schools

Based on the measurement of sound levels in decibels (dBA), schools did not comply with the recommended standards set by ANSI S12.60, which defines an ideal classroom noise level as not exceeding 35 dBA. The data revealed that all classrooms recorded sound levels significantly above this threshold, with most readings ranging from 50 to over 60 dBA. This indicates that the acoustic environment in the classrooms exceeds acceptable limits and may negatively impact teaching and learning processes.

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Table 2: Correlation coefficients are reported. (p < .05. ** p < .01)

g	1	2	3	4	5	6	7	8	9
1. Satisfaction	—				.13*				
2. Conflict	0.12	—	.94**	.90**	.91**				
3. Competitive	0.08	.94**	—	.93**	.89**				
4. Difficulty	0.13	.90**	.93**	—	.91**				
5. Cohesion	.13*	.91**	.89**	.91**	—				
6. Space	0	−.06	−.05	−.07	−.06	—	.77**	1.00**	.77**
7. Noise	0.1	−.02	−.02	−.04	−.02	.77**	—	.77**	1.00**
8. Lighting	0	−.06	−.05	−.07	−.06	1.00**	.77**	—	.77**
9. Temperature	0.1	−.02	−.02	−.04	−.02	.77**	1.00**	.77**	—

Strong positive correlations were observed among the psychosocial variables of conflict, competitive behavior, difficulty, and cohesion, with correlation coefficients ranging from r = .89 to .94, all significant at the p < .01 level. This indicates that as one of these factors increases, the others are likely to increase as well, suggesting a tightly interconnected psychosocial climate among students. Satisfaction was found to have a weak but significant positive correlation with cohesion (r = .13, p < .05), indicating that greater student cohesion is slightly associated with increased satisfaction in the classroom environment.

Among the physical environmental variables, extremely high positive correlations were noted between space, noise, lighting, and temperature (ranging from r = .77 to 1.00, p < .01). This suggests that these physical factors tend to vary together—when one increases, the others do as well. The perfect correlation between space and lighting as well as space and temperature (r = 1.00**) may reflect overlapping measurement parameters or spatial design elements that simultaneously affect multiple environmental conditions. Interestingly, no significant relationships were found between most psychosocial and physical environmental factors, with the exception of the weak correlation between satisfaction and cohesion, and the inter-correlations among the physical environment factors themselves. This may imply that while psychosocial and physical elements are both important in the classroom environment, they may operate somewhat independently in influencing student outcomes. Overall, the findings highlight two key clusters of related variables—psychosocial dynamics and physical conditions—each playing a distinct but vital role in shaping the learning environment.

A multiple linear regression analysis was performed to determine whether Satisfaction, Conflict, Competitive Behavior, Difficulty, and Cohesion predicted the dependent variable (e.g., engagement or performance). The results

indicated that Satisfaction (β = .886, p < .001), Conflict (β = −.346, p < .001), Difficulty (β = .323, p < .001), and Cohesion (β = .458, p < .001) were significant predictors. However, Competitive Behavior was not a significant predictor (β = −.205, p = .086). These findings suggest that while Satisfaction, Difficulty, and Cohesion have a positive impact on the outcome, Conflict significantly negatively affects it.

Table 3: Result of Multiple Regression Analysis

Predictor	**B**	**SE**	**β**	***t***	***p***
Satisfaction	1.557	0.226	0.886	6.889	< .001
Conflict	-0.451	0.108	-0.346	-4.192	< .001
Competitive	-0.205	0.118	-0.205	-1.727	0.086

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Difficulty	0.381	0.077	0.323	4.928	< .001
Cohesion	0.724	0.076	0.458	9.589	< .001

Note: B = unstandardized coefficient; SE = standard error; β = standardized beta coefficient.

Table 4. Result of Mediator Analysis for Direct and Indirect Effects

IV	Indirect Effect (BootSE)	Indirect Sig.	Direct Effect	Direct Sig.
Satisfaction	−1.2602 (1.6507)	Not Significant	2.3968	$p < .001$
Conflict	1.6397 (0.2873)	Significant	−0.9414	$p = .0003$
Competition	0.1555 (0.1175)	Not Significant	0.4912	$p < .001$
Difficulty	0.0404 (0.0473)	Not Significant	−0.5279	$p < .001$
Cohesion	0.2356 (0.0333)	Significant	0.9628	$p < .001$

A mediation analysis was performed to assess whether indirect effects existed for each predictor variable via an unspecified mediator (e.g., motivation, emotional state). Satisfaction showed no significant indirect effect (Effect = −1.2602, BootSE = 1.6507), but a significant direct effect (Effect = 2.3968, p < .001). Conflict showed significant indirect (Effect = 1.6397, BootSE = 0.2873) and direct effects (Effect = −0.9414, p < .001), indicating partial mediation. Competition had a non-significant indirect effect (Effect = 0.1555, BootSE = 0.1175), but a significant direct effect (Effect = 0.4912, p < .001). Difficulty also had a non-significant indirect effect (Effect = 0.0404, BootSE = 0.0473), and a significant direct negative effect (Effect = −0.5279, p < .001). Cohesion showed significant indirect (Effect = 0.2356, BootSE = 0.0333) and direct effects (Effect = 0.9628, p < .001), indicating partial mediation.

DISCUSSION AND CLASSROOM ENVIRONMENT STANDARD

Based on the findings, the recommended standard values for a conducive classroom environment are as follows: a minimum lighting level of 500 lux, a temperature not exceeding 32.5°C, noise levels below 35 dBA, classroom space between 1.39 m^2 and 2.72 m^2 per student, and a minimum psychosocial score of 3.62. The study highlights that both environmental and psychosocial factors are interdependent in creating comfortable classroom conditions for students.

Malaysia experiences a tropical climate characterized by consistently hot and humid conditions throughout the year. The comfortable humidity range for tropical regions is typically between 30% and 75%, while the ideal temperature lies between 22°C and 27°C (CSCTP, 1983). Abdul Malik (2000) identified the thermal comfort range for Malaysia as between 25.5°C and 28°C However, this study found that classroom temperatures frequently exceeded 27°C, with recorded values ranging from 27.4°C to 31.7°C. These elevated temperatures can cause discomfort, particularly in overcrowded classrooms or those exposed to direct sunlight without adequate shading. As noted by Kruger and Zannin (2004), hot classroom conditions reduce students' comfort and negatively affect their focus on learning.

Wong (2003) reported a neutral classroom temperature of 28.8°C in Singapore, indicating that comfort levels may vary depending on regional climate adaptation. Baruti et al. (2019) further emphasized that neutral temperatures are influenced by local climate patterns, seasonal variations, and the thermal adaptation of occupants. Supporting this, Azizpour et al. (2014) conducted a study at the National University of Malaysia Hospital and found, using regression analysis and the Predicted Mean Vote (PMV) model, that an acceptable temperature range for human comfort lies between 23.8°C and 29°C.

In addition to thermal conditions, lighting plays a significant role in creating a conducive classroom environment. According to Farzam (2011), lighting levels near classroom windows in Iran ranged from 300 to 500 lux, meeting acceptable standards. Similarly, a study in Korea found that on sunny days, lighting levels near classroom windows

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could exceed 1500 lux (Hae et al., 2003). Galasiu and Veitch (2006) emphasized that bright lighting contributes to a more comfortable environment and reduces stress compared to artificial lighting. It also positively impacts students' health, attendance, academic performance, and physical development (Hathway, 1995). Furthermore, Sojoudi and Jaafar (2012) noted that efficient use of natural daylight can reduce reliance on fluorescent lighting, thereby lowering energy costs.

Despite these benefits, measurements in this study revealed that lighting levels in most classrooms—both before and after breaks—remained below the 500 lux standard established by SIRIM (2018), contributing to student discomfort. As windows serve as a key source of natural light (Kruger & Zannin, 2004), classrooms with larger window areas exhibited higher lighting levels, particularly in spaces that allowed more direct sunlight penetration.

These findings collectively underscore the importance of optimizing both environmental (thermal and lighting) and psychosocial factors in ensuring student comfort and enhancing learning outcomes.

The psychosocial aspect in this study recorded a relatively high mean score of 3.62, suggesting that students remain disengaged with several classroom dynamics such as satisfaction, conflict, competition, challenges, and cohesion. Most students expressed dissatisfaction with the classroom environment during teaching and learning sessions. This indicates that thermal discomfort may contribute not only to physical unease but also to psychological issues, including increased conflict and diminished well-being. Notably, Jansz (2011) highlighted that such discomfort can lead to health-related symptoms such as fatigue, lethargy, skin rashes, dry lips, and general physical decline.

In addition to thermal and psychosocial discomfort, noise pollution represents a significant concern. Several past studies have shown that noise levels in many school environments exceed recommended background noise thresholds (Shield & Dockrell, 2008; Tong et al., 2017). The Noise Criterion (NC) rating is commonly used to assess indoor noise levels, with classrooms ideally maintaining noise levels between NC25 and NC30 (Raichel, 2006).

Traffic and external noise sources contribute to a range of issues, including teaching interruptions, the need for teachers to raise their voices, closing windows, and repeating instructions (Karami et al., 2012; Bakar, 2012). Enmarker and Boman (2004) identified various sources of classroom noise, including road traffic, playground activity, hallway chatter, classroom conversations, and the movement of furniture. These noises may originate from either within the classroom or the surrounding environment. Interviews with both students and teachers revealed that disturbances came from both sources, though external noise was more difficult to control and had a more significant impact on student concentration.

Although no universal standards for maximum classroom noise levels exist, some countries provide national guidelines. For instance, Brazil's regulatory body has set the maximum permissible classroom noise level at 40 dB(A) (Zannin & Marcon, 2007). However, the same study found that actual noise levels often exceeded this threshold in all five tested classroom scenarios, regardless of whether windows were open or closed. Furthermore, both students and teachers identified classroom noise as a primary source of distraction during learning activities.

An organized physical classroom environment is crucial for ensuring that learning can proceed smoothly and effectively, thereby contributing to academic excellence (Syed Ismail & Ahmad Subki, 2010). Mok (2008) emphasized that the physical aspects of a classroom—such as spatial size and furniture layout—must align with the number of students. When student numbers exceed the room's optimal capacity, it can lead to discomfort and disrupt the learning atmosphere, often resulting in disciplinary issues.

Given the limited space in most classrooms, careful planning is required for student seating, movement paths, and the arrangement of chairs, desks, and other facilities. Graca et al. (2007) found that up to 40% of classroom congestion results from poor spatial organization. However, determining the precise space needed per student is challenging, as desk arrangements frequently change depending on classroom activities and student movement. As a result, the usable space per student is typically assessed as an average.

This research advocates for the implementation of teaching strategies that are supported by appropriate classroom infrastructure and physical conditions. These physical aspects are closely interrelated with the psychosocial dimensions of learning, such as student emotions and peer interactions. A positive learning environment contributes significantly to student performance (Salina et al., 2009). Similarly, Brackett et al. (2011) demonstrated that supportive classroom environments positively influence student behavior through emotional engagement. Sriklaub et al. (2015) described the classroom environment as a dynamic combination of teacher behaviors (e.g., instructional methods and communication), student behaviors (e.g., motivation, cooperation, and engagement), and the emotional outcomes of these interactions.

This study identifies four key physical environmental factors—lighting, ventilation, noise, and space—as primary contributors to the psychosocial dimensions of student experience. These include subconstructs such as satisfaction, conflict, competition, difficulty, and cohesion. The findings suggest that students' perceptions of the classroom environment and their psychosocial well-being are closely linked to their comfort and success in teaching and learning processes. Zandvliet (1999) asserted that a well-equipped classroom fosters a strong relationship between student satisfaction and the psychosocial environment. Given that satisfaction significantly affects student motivation, educators and school administrators must consider both physical and psychosocial factors in efforts to enhance learning effectiveness. As Zhao (2010) concluded, a supportive classroom and school climate has a positive and motivating impact on students.

CONCLUSION

The findings of this study contribute valuable insights for the Ministry of Education and schools in achieving more effective outcomes related to classroom infrastructure and student psychological well-being. Although the scope of this research is limited to primary school students, the results offer practical recommendations that can serve as a reference for enhancing the teaching and learning process in classroom settings. The study identified four key physical predictor variables—lighting, ventilation, thermal conditions, and space—that significantly influence student collaboration. These physical factors are closely linked to the psychosocial aspects of the learning environment. The established physical standards for classroom environments should therefore be considered in tandem with psychosocial indicators to ensure student comfort and optimal learning conditions. These findings clearly highlight the interdependence between the physical environment and the psychosocial climate in supporting effective learning.

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