Modelling physical ergonomics and student performance in higher education: the mediating effect of student motivation

Muhammad Safuan Abdul Latip
Faculty of Hotel and Tourism Management, Universiti Teknologi MARA Cavangan Terengganu, Kampus Dungun, Dungun, Malaysia and Asia Pacific Centre for Hospitality Research, School of Hospitality and Service Management, Sunway University, Bandar Sunway, Malaysia

Siti Nur Nadhirah Abdul Latip
Tun Razak Graduate School, Universiti Tun Abdul Razak, Kuala Lumpur, Malaysia

Masliana Tamrin
Faculty of Business and Management, Universiti Teknologi MARA Cavangan Melaka, Kampus Alor Gajah, Alor Gajah, Malaysia, and

Faizatul Akmal Rahim
Pusat PERMATA@Pintar Negara, Universiti Kebangsaan Malaysia, Bangi, Malaysia

Abstract

Purpose – The study aims to explore factors that influence students' academic performance in the context of physical ergonomics and assess the mediating effect of motivation between lighting, noise, temperature, chair design and students' performance from the student's perspective.

Design/methodology/approach – The research was categorised as a correlational study and employed non-contrived and cross-sectional methods to achieve its objectives. The target population was university students aged 18 years old and above enrolled in Malaysia’s higher education institutions. Due to the inaccessibility of the sample frame, convenience sampling, a type of non-probability sampling, was utilised. Data collection was conducted through an online survey primarily distributed among student groups.

Findings – The study's findings reveal that only two exogenous variables, lighting and noise, directly influence students' performance. Additionally, motivation is a potent and significant factor in shaping students' performance. Motivation is also identified as a mediator in the complex relationship between lighting, noise, temperature and student performance. Surprisingly, although temperature does not directly influence student performance, it indirectly influences performance through motivation.

Originality/value – This study is an original exploration into the intricate factors shaping students' academic performance within the domain of physical ergonomics from a student perspective. The research uniquely investigates the mediating impact of motivation on the relationships between lighting, noise, temperature, seating arrangements and academic outcomes. The findings will contribute novel insights to the existing body of knowledge.

Disclosure statement: No potential conflict of interest was reported by the authors.

Ethical statement: The manuscript contains original work and properly cites and references any external sources or prior research. Furthermore, we confirm that all respondents willingly agreed to participate in the study.

Data availability statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.
of knowledge, offering a distinct perspective on the complex dynamics that influence student learning experiences and performance in educational settings.

**Keywords** Physical ergonomics, Motivation, Student, Academic performance, Higher education

**Paper type** Research paper

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**Introduction**

The unprecedented onset of the severe COVID-19 pandemic in 2020 precipitated a seismic shift in educational paradigms, propelling learning into the virtual realm (Abdul Latip and Tamrin, 2023). Universities and higher education institutions rapidly undertook adaptations, fortifying their online infrastructure to facilitate more stringent enforcement of quarantine measures (Latip et al., 2020). This transformative period has ushered in significant alterations that rippled across the educational landscape, affecting virtually all students (Khlaif et al., 2023). In the virtual classroom, students grappled with the need to employ novel coping mechanisms during lessons, which could carry latent implications for specific aspects of ergonomics (Gumasing and Castro, 2023).

Consequently, a pressing need emerged for ergonomics research methods that could mitigate student fatigue and discomfort while enhancing workplace safety, a pursuit driven by the imperative to boost productivity (Gumasing and Castro, 2023). Meanwhile, students have been thrust into the unfamiliar terrain of their home environments, grappling with a myriad of obstacles. These obstacles range from issues of physical comfort to the disruptive presence of family members or siblings, not to mention the unpredictable and often uncomfortable fluctuations in temperature (Makhbul and Idurs, 2009). Amid these challenges, the intricate interplay of physical ergonomics inevitably exerts a direct and substantial impact on students’ motivation levels, particularly against the backdrop of a global pandemic (Janc et al., 2023). Hence, it becomes increasingly critical to conduct studies that adapt to the evolving landscape of higher education worldwide. This adaptation is particularly pertinent given the shift towards personalised learning spaces (Thi et al., 2023).

Recent research has concentrated chiefly on evaluating the suitability and effectiveness of digitalisation in education, particularly in response to the COVID-19 pandemic, which has emphasised study in the area of physical ergonomics and student performance (Abdul Latip and Tamrin, 2023; Janc et al., 2023; Soltaninejad et al., 2021).

Drawing upon the research of Mazalan and Shafie (2021), a potentially significant correlation emerges between ergonomics and students’ comfort levels. Sharp contrasts are noted among students exposed to high noise and temperature levels during sessions. The symbiotic interaction between students and their immediate surroundings highlights the importance of environmental ergonomics in improving workplace designs and promoting students’ comfort (Janc et al., 2023; Keser Aschenberger et al., 2023; Soltaninejad et al., 2021).

Fostering students’ interest and motivation in learning is a pivotal objective in higher education, crucial for both individual success and the advancement of society. However, achieving this goal relies heavily on managing various environmental factors within educational settings. Studies such as those by Soltaninejad et al. (2021) emphasise the significance of classroom aesthetics, layout, lighting, ventilation, interior design, and instructional equipment in shaping students’ engagement and commitment to learning.

Conversely, suboptimal learning conditions have been shown to precipitate disinterest and undermine student motivation. Despite the wealth of research advocating for the deliberate incorporation of elements like classroom colour, design, lighting, ventilation, and technology to ignite motivation (Houghton et al., 2001), there needs to be more attention towards the physical ergonomics of learning environments. As highlighted by Zunjic et al. (2015), empirical evidence underscores the profound impact that the choice of furniture, including high furniture, sit-stand options, tilt tables, and chairs, can have on students’ motivation and...
performance goals. Yet, providing ergonomic tables and chairs, which could significantly enhance students’ comfort, performance, and overall productivity by supporting their physical well-being, remains an overlooked intervention (Gumasing and Castro, 2023).

However, there remains a noticeable gap in research concerning the physical ergonomics of learning environments particularly from student perspective on their potential motivation and academic performance (Keser Aschenberger et al., 2023). The significance of comprehending and enhancing the physical ergonomics of learning environments is crucial as personalised learning spaces and online learning become more prevalent, particularly in remote and personalised learning modalities (Janc et al., 2023). Without addressing these fundamental aspects, efforts to bolster students’ motivation and academic performance may fall short, hindering their potential for excellence in an ever-changing educational landscape (Abdul Latip et al., 2020). Therefore, there is a pressing need for research that explores students’ perceptions of their potential academic performance in relation to these challenges. Investigating how physical ergonomics and learning environment adaptations influence students’ comfort and performance can offer insights into enhancing their academic experiences (Janc et al., 2023). By examining students’ perceptions, the study captures their firsthand experiences with environmental factors such as lighting, noise, temperature, and seating arrangements, all of which significantly shape their learning and engagement (Abdul Latip and Tamrin, 2023).

Understanding students’ personal views on these factors can provide insights into the nuanced ways in which physical ergonomics impacts academic performance. This perspective is crucial for identifying specific challenges students face and opportunities for improvement in their learning environments. The study’s approach acknowledges that academic performance is not solely dependent on individual effort but is intricately linked to the surrounding environment, including classroom acoustics, colour schemes, and comfort levels (Abdul Latip et al., 2022; Heidarimoghadam et al., 2022).

By delving into these dynamics, we can better understand how to optimise learning conditions and bolster students’ potential for academic excellence in a rapidly evolving educational landscape, as supported by previous scholars (Keser Aschenberger et al., 2023; Soltaninejad et al., 2021). By taking into account the perspective of students, this research endeavours to address the crucial research questions below effectively:

**RQ1.** What factors influence students’ academic performance in the context of physical ergonomics?

**RQ2.** Does motivation mediate the relationship between lighting, noise, temperature, chair design, and student’s academic performance?

**Literature review**

*Theoretical foundation: the habitability pyramid*

As Vischer (2007) proposed, the habitability pyramid provides a theoretical framework that offers valuable insights into the relationship between environmental comfort and performance in various settings, including class settings (Omar et al., 2012). This model delineates three critical dimensions of comfort: physical, functional, and psychological. Each dimension shapes individuals’ experiences and behaviours within their environment. The physical comfort dimension encompasses fundamental human needs such as security, cleanliness, and accessibility. These aspects are essential for creating a conducive environment that promotes well-being, productivity, and learning. The concept of physical comfort is highly relevant in the context of the study on physical ergonomics and student performance in higher education. It underscores the importance of ergonomic furniture, proper lighting, adequate ventilation, and other environmental factors directly impacting students’ physical well-being and comfort within learning spaces (Vischer, 2007).
Functional comfort, conversely, pertains to the ergonomic support provided to users in carrying out their tasks and activities (Vischer, 2007). This dimension encompasses elements such as the availability of suitable furniture, lighting arrangements, and the provision of meeting spaces. In higher education, ensuring functional comfort involves designing learning environments that facilitate effective studying, collaboration, and student engagement. By integrating the habitability pyramid framework into the study, researchers can understand the multifaceted nature of environmental comfort and its impact on student performance and motivation in higher education (Omar et al., 2012).

Academic performance
Academic performance is a multifaceted and critical aspect of a student’s educational journey, reflecting their level of knowledge and achievement in specific subjects. It serves as a yardstick to assess how well a student meets the established standards, typically aligned with their age and educational level (Jimenez, 2000). According to Hassan et al. (2020), academic performance encompasses a broad spectrum of accomplishments and outcomes in the context of one’s educational experiences. However, it is essential to emphasise the need for greater consistency and precision when measuring academic success in research studies (Hassan et al., 2020).

Recent research findings, as exemplified by the study conducted by Gad et al. (2022), have shed light on the significant impact of environmental factors on students’ learning abilities and, consequently, their academic performance. These factors encompass a range of elements, including classroom acoustics, lighting conditions, colour schemes, temperature settings, and seating arrangements. Such environmental factors have been found to exert a notable influence on students’ engagement, motivation, and overall learning experiences besides lecturer competency (Abdul Latip et al., 2020).

For instance, adequate classroom lighting can contribute to better focus and reduced eye strain, positively affecting a student’s ability to absorb and retain information. Similarly, appropriate seating arrangements can encourage student interaction and collaboration, fostering a more engaging and effective learning environment. Moreover, factors such as room temperature and colour schemes can influence students’ comfort and mood, further impacting their motivation and academic performance (Gad et al., 2022).

Given the substantial impact of these environmental factors on academic success, educational institutions increasingly recognise the importance of creating conducive learning environments. Schools and universities are actively seeking ways to optimise their physical spaces, ensuring they are well-designed and equipped to enhance students’ educational experiences. This holistic approach to education acknowledges that academic performance is not solely dependent on individual effort but is intricately linked to the surrounding environment (Latip et al., 2022).

Importantly, the study’s focus on students’ personal perceptions of their potential academic performance in relation to physical ergonomics is crucial for a holistic understanding of academic success. By examining firsthand experiences with environmental factors such as lighting, noise, temperature, and seating arrangements, the study identifies challenges and opportunities for improvement in learning environments. Prioritising students’ views highlights the impact of physical ergonomics on engagement and motivation, guiding educational institutions to optimise learning spaces for better academic achievement. This approach acknowledges the interconnectedness between students’ surroundings and their potential for success (Abdul Latip and Tamrin, 2023).

Noise
Noise pollution poses a significant threat to student learning environments, yet it remains inadequately addressed despite its well-documented adverse effects on concentration and cognitive function (El Yamlahi Chahdi et al., 2024). There’s a noticeable gap in research
focussing specifically on noise’s effects within educational settings, although a recent study highlighted that learning spaces in an open environment and the observance of social distancing can affect the quality of the student’s ability to concentrate, which could potentially influence their academic performance (Soltaninejad et al., 2021). Addressing this gap is critical to optimising learning conditions and ensuring student success (Abdul Latip and Tamrin, 2023). Proactive measures, including soundproofing classrooms and creating designated quiet zones, are imperative for fostering conducive learning environments that support students’ concentration and academic performance, which aligns with previous study on task performance (Koopsman et al., 2012).

In educational settings, noise plays a multifaceted role, as excessive classroom noise can be a formidable barrier to effective learning, hindering students’ physical endurance, study performance, and motivation (Chere and Kirkham, 2021). Moreover, it exacerbates hearing and communication issues, further complicating the learning process. As Soltaninejad et al. (2021) highlighted, external noise can also significantly disrupt the classroom environment, impacting students’ emotional states and the dynamics of teaching. Interestingly, research reveals that not all noises are equal in terms of their effects. Moderate noise levels have been shown to promote relaxation and creative thinking, but when noise reaches excessive levels, it hinders concentration. These effects vary among individuals, making it a complex issue to navigate as learning environments play a vital role in supporting learners’ motivation by providing comfort, promoting positive psychological states, and enhancing learners’ concentration (Gumasing et al., 2023).

The influence of noise on academic performance cannot be overstated, as evident in the research conducted by Realyvásquez-Vargas et al. (2020) and Abu Bakar et al. (2021), which emphasise the significant and far-reaching impact of noise on students’ educational outcomes. These findings collectively highlight the urgency of addressing noise pollution, particularly within educational environments, where its effects on learning, emotional well-being, and academic achievement are profound. Therefore, the following hypotheses are proposed:

\[ H1. \] Noise level significantly influences student performance.

**Lighting**

Our comprehension of the world hinges significantly on visual perception, underlining light’s critical role in shaping our awareness and cognitive processes (Barrett et al., 2016). Surprisingly, approximately 83% of learning is attributed to light’s influence, underscoring its paramount importance in educational settings (Soltaninejad et al., 2021).

According to Wohlfarth (1986), the quality of interior lighting plays a vital role in shaping the academic experiences of undergraduate students. This finding highlights the significance of interior lighting quality as a central determinant that impacts various facets of students’ academic lives. Notably, research indicates that lighting quality significantly affects motivation levels, educational achievements, concentration, cognitive abilities, and perceptions of comfort among students. Furthermore, extensive studies have explored and documented the correlation between lighting conditions and the overall comfort experienced in specific environments. However, despite the wealth of research in this area, there persists a need to delve deeper into the nuanced aspects of light quality, as suggested by Baaﬁ (2020).

It’s crucial to recognise the distinction between natural and artificial lighting, as elucidated by Saini (2022). Natural light originates from sources such as sunlight, while artificial light is derived from electric bulbs and fixtures. In educational contexts, the lighting within classrooms holds significant importance, not only for its potential to affect students’ academic performance but also for preserving their eye health.

Subpar lighting conditions can lead to discomfort and headaches among students, highlighting the importance of optimal lighting design. Baaﬁ (2020) emphasises that lighting
exerts a multifaceted impact, influencing aspects like vision, circadian rhythms, emotional states, and cognitive processes. Each of these factors plays a distinct role in shaping the effectiveness of the learning process.

Building on this foundation of research, a recent study conducted by Realyvásquez-Vargas et al. (2020) has substantiated the significant influence of lighting on the academic achievements of university students. Their findings reinforce and extend the implications of earlier research, emphasising that the quality and design of lighting within educational environments should not be underestimated.

In light of these collective insights, it becomes increasingly apparent that lighting conditions profoundly influence the overall learning experience. However, despite acknowledging the significance of lighting in influencing student motivation and performance, comprehensive studies exploring the nuanced effects of different lighting conditions are lacking. This research gap presents an opportunity to deepen our understanding of the complex interplay between lighting quality and its impact on student learning outcomes. Addressing lighting considerations comprehensively is crucial for creating learning environments conducive to student engagement, comfort, and academic success. Therefore, the following hypotheses are proposed:

**H2.** Room lighting significantly influences student performance.

*Temperature*

Increased temperature and humidity can cause discomfort in students, leading to decreased performance due to a lack of concentration (Heidarimoghadam et al., 2022; Soltaninejad et al., 2021). Researchers are currently directing their efforts toward determining the optimal learning temperature, recognising its profound impact on students’ comfort during study sessions and its pivotal role in influencing academic performance. Indeed, lighting is one of the factors in creating a safe and comfortable environment and is closely related to human productivity (Fadillah et al., 2020).

Striking a delicate balance between warmth and cold is critical to fostering an environment conducive to learning. Studies have shown that elevated temperatures can adversely affect students’ comfort and academic performance. In such conditions, students often struggle to concentrate, experience increased perspiration, and maintain focus and productivity. As Earthman (2002) suggested, a more relaxed environment, ideally maintained at 20 and 24 °C, can significantly enhance students’ academic achievements. Students benefit from improved concentration, heightened comfort, enhanced effectiveness, sharper focus, and increased productivity during study sessions within this temperature range. Indeed, a room temperature of 29 °C gives a significant difference in the student’s stress level compared to the temperature of 21 and 25 °C (Fadillah et al., 2020).

The positive impact of temperature on academic performance has been unequivocally demonstrated in research conducted by Realyvásquez-Vargas et al. (2020) and Wargocki et al. (2019). Their findings affirm the significance of temperature and emphasise its consistency in improving students’ academic outcomes across various educational levels, from primary schools to universities. Furthermore, the study undertaken by Phan (2021) delves into the intricate relationship between temperature and students’ educational achievements. The research findings reveal intriguing nuances in how temperature affects learning outcomes. Male students, it appears, tend to exhibit improved academic performance as temperatures rise. In contrast, female students demonstrate enhanced performance even in cooler conditions, suggesting a complex interplay between environmental factors and learning outcomes.

The quest for the optimal learning temperature represents a significant area of interest among researchers due to its direct impact on students’ comfort and academic success. The balance between warm and cool environments is pivotal in creating conditions that promote
effective learning. The insights gleaned from these studies underscore the importance of temperature regulation in educational settings and reveal the multifaceted nature of its effects on students, emphasising the need for tailored approaches to temperature control in pursuing academic excellence (Fadillah et al., 2020). Therefore, the following hypotheses are proposed:

**H3.** Room temperature significantly influences student performance.

**Chair design**
The absence of ergonomically designed chairs in classrooms or homes for self-learning settings has far-reaching consequences, as it compels students to adopt unconventional postures that can severely hinder their educational achievements. Prolonged periods of sitting in poorly designed chairs often force students into awkward stances, leading to discomfort and the potential for long-term health issues, especially due to the inadequate support provided to the spine (Symanzik et al., 2023). This subpar chair design has a pronounced negative impact on student’s academic performance, given that they spend extended periods sitting during lectures, discussions, and exams, which can result in physical discomfort and underscores the urgent need for improved seating arrangements (Paradina and Prasetyo, 2023).

Prior research conducted by Castellucci et al. (2016) shed light on the positive correlation between school furniture, including chairs, and student performance. Their findings suggest that well-designed furniture can enhance students’ academic achievements. Similarly, the study conducted by Alani and Hawas (2021) underscores the significance of elements within the learning environment, including chairs, in promoting and favouring improved student performance. Meanwhile, another study revealed that students were exposed to discomfort, particularly in the lower back, upper back and hips/buttocks, when sitting between 7 to 8 h and 9 to 10 h a day when doing their online classes, and the effect was believed to be even worse for those student with poor study chair (Paradina and Prasetyo, 2023).

These insights collectively emphasise the pivotal role that ergonomically designed chairs can play in creating an educational environment that enhances students’ comfort and positively influences their academic outcomes (Paradina and Prasetyo, 2023). Investing in proper seating arrangements can yield substantial benefits, fostering an atmosphere conducive to learning and well-being, ultimately contributing to students’ educational success. Therefore, the following hypotheses are proposed:

**H4.** The design of the chair significantly influences student performance.

**Motivation**
Motivation is widely recognised as a powerful force that shapes human behaviour and profoundly influences individuals’ actions. In the realm of academia, this concept takes on particular significance. Hulleman et al. (2016) define academic motivation as an intrinsic inclination among students to wholeheartedly engage with the process of learning and their broader educational experiences. This definition underscores a genuine desire to acquire knowledge and transform the educational journey into a rewarding and enlightening endeavour.

Building upon this foundation, Brophy (1983) classified student academic motivation into two distinct categories: “state motivation” and “trait motivation”. State motivation relates to the current drive to engage in and persist with an activity, driven by an innate interest in the task and its pleasure. On the other hand, trait motivation represents a consistent and enduring inclination influenced by individual traits, such as personality traits.
Indeed, these distinctions in academic motivation underscore the multifaceted nature of what propels students toward their educational goals. Whether it is the immediate pleasure derived from a task or the enduring impact of one’s inherent traits, comprehending these facets of motivation is paramount for educators and researchers alike. Such understanding provides a foundation for building strategies to bolster students’ engagement and pave the way for their success in the educational journey.

Moreover, it is crucial to acknowledge a notable deficiency in existing research—a lack of exploration into the relationship between physical ergonomics and motivation concerning student performance. This gap presents a significant challenge within the current scholarly landscape. Investigating this nexus holds promise for uncovering valuable insights into how the physical learning environment, encompassing elements such as seating, lighting, and comfort, shapes students’ motivation levels and, consequently, their academic outcomes. Addressing this research void has the potential to provide educators and researchers with a more nuanced understanding of how physical ergonomics influences student motivation. Such insights can inform the development of more effective educational environments and strategies tailored to enhance student engagement and performance. Therefore, the formulation of hypotheses to investigate this connection is warranted.

\[ H5. \text{ Motivation significantly influences student performance.} \]
\[ H6. \text{ Noise level significantly influences student motivation.} \]
\[ H7. \text{ Room lighting significantly influences student motivation.} \]
\[ H8. \text{ Room temperature significantly influences student motivation.} \]
\[ H9. \text{ The design of the chair significantly influences student motivation.} \]
\[ H10. \text{ Student motivation mediates the relationship between noise level and student performance.} \]
\[ H11. \text{ Student motivation mediates the relationship between room lighting and student performance.} \]
\[ H12. \text{ Student motivation mediates the relationship between room temperature and student performance.} \]
\[ H13. \text{ Student motivation mediates the relationship between chair design and student performance.} \]

**Methodology**
The research study was classified as correlational and utilised non-contrived and cross-sectional methods. The target population comprised active undergraduate university students aged 18 years and above who were enrolled in Malaysia’s higher education institutions. Undergraduate students were targeted due to their significant representation within higher education institutions, rendering them a pertinent and easily accessible research group. Moreover, undergraduate students commonly navigate substantial transitions in their academic journey, encountering diverse challenges and opportunities that can influence their academic performance and motivation. Given the constraints regarding access to the sample frame, convenience sampling, a non-probability sampling method, was employed. Convenience sampling provides practical benefits such as feasibility, cost-effectiveness, and timely data collection, mainly when there are limited resources, time, or access to the target population. Although convenience sampling may introduce some bias due to the non-random selection of participants, steps were taken to mitigate this bias by
ensuring diverse recruitment channels and representative participant demographics were considered. Additionally, robust statistical analyses were conducted to account for potential biases and ensure the reliability and validity of the study’s findings.

Data was collected through an online survey, primarily distributed among student groups. This approach was deemed feasible due to the increasing digitisation of higher education. A Likert scale with five measurement points was employed to ensure respondents’ ease in accurately positioning themselves, as having too many or too few points on the scale could pose challenges. Furthermore, the survey instrument was distributed in English. The study required a minimum sample size of 210, based on Hair et al. (2017) recommendation, considering the inclusion of 21 survey items. After eliminating invalid data, 427 valid responses were included in the analysis, meeting the required sample size.

Prior to hypothesis testing, the data underwent cleaning and screening processes. Notably, respondents participated voluntarily in the survey. The researchers used the Statistical Package for Social Sciences (SPSS) for data preparation, cleaning, and analysis. Meanwhile, the study applied Partial Least Squares Structural Equation Modelling (PLS-SEM) with bootstrapping technique through SmartPLS software for instrument validation and hypothesis testing. Bootstrapping allows for estimating standard errors and confidence intervals without relying on the assumption of normality, utilising resampling techniques from the observed data (Hair et al., 2017).

The study incorporated six constructs: noise, room lighting, room temperature, chair design, motivation, and student performance. The instruments used were adapted and adopted from previous reliable and validated research studies in physical ergonomics and performance (Abdul Latip et al., 2022; Koopmans et al., 2012; Latip et al., 2022; Mohamed Makhbul et al., 2009).

Data analysis

Respondent profile

Based on the findings of the descriptive analysis displayed in Table 1, a more significant proportion of participants in the study were female (54.4%) compared to male participants (45.6%). Regarding age groups, the highest percentage of respondents fell within the 18–20 years old category (66.9%), followed by the 21–23 age range (30.9%) and the 24 and above (2.2%). As for student status, most respondents (99.0%) identified as full-time students, while 1.0% were part-time students.

Reliability and validity analysis

Table 2 indicates that all constructs’ composite reliability (CR) exceeded 0.60, indicating good reliability according to Hair et al. (2017). All constructs also achieved an Average Variance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Frequency</th>
<th>Per cent %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>195</td>
<td>45.6</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>232</td>
<td>54.4</td>
</tr>
<tr>
<td>Age (Years old)</td>
<td>18–20</td>
<td>286</td>
<td>66.9</td>
</tr>
<tr>
<td></td>
<td>21–23</td>
<td>132</td>
<td>30.9</td>
</tr>
<tr>
<td></td>
<td>24 and above</td>
<td>9</td>
<td>2.2</td>
</tr>
<tr>
<td>Student status</td>
<td>Full time</td>
<td>423</td>
<td>99.0</td>
</tr>
<tr>
<td></td>
<td>Part-time</td>
<td>4</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>427</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 1. Demographic profile

Source(s): Authors’ own sources
Extracted (AVE) above 0.50. Therefore, the study concludes that convergent validity for the constructs was attained (Hair et al., 2017). Furthermore, the instruments used in the study were validated for discriminant validity using the heterotrait-monotrait ratio of correlations (HTMT criterion). Discriminant validity was confirmed as the HTMT scores were below 0.85 (see Table 2).

**Direct path analysis**

The study employed 5,000 bootstrap samples to investigate the direct relationships between variables, as depicted in Figure 1. The analysis results are presented in Table 3 and were considered statistically significant if the t-value exceeded 1.96 and the p-value was less than 0.05. Out of the nine hypotheses proposed, seven were found to have significant outcomes.

Firstly, a significant relationship between noise and student performance was discovered, supporting H1 (NOI → SPER; β = 0.171, t = 3.172, p = 0.002). The findings suggest that when noise in the learning environment is effectively controlled, student performance increases by

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**Table 2. CR, AVE and validity summary analysis**

<table>
<thead>
<tr>
<th>Constructs</th>
<th>CR</th>
<th>AVE</th>
<th>CHA</th>
<th>LIG</th>
<th>MOT</th>
<th>NOI</th>
<th>SPER</th>
<th>TEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHA</td>
<td>0.920</td>
<td>0.853</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIG</td>
<td>0.820</td>
<td>0.639</td>
<td>0.346</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOT</td>
<td>0.927</td>
<td>0.871</td>
<td>0.172</td>
<td>0.688</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOI</td>
<td>0.581</td>
<td>0.543</td>
<td>0.335</td>
<td>0.783</td>
<td>0.724</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>SPER</td>
<td>0.797</td>
<td>0.534</td>
<td>0.282</td>
<td>0.721</td>
<td>0.694</td>
<td>0.769</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEM</td>
<td>0.736</td>
<td>0.630</td>
<td>0.431</td>
<td>0.705</td>
<td>0.594</td>
<td>0.770</td>
<td>0.629</td>
<td></td>
</tr>
</tbody>
</table>

Source(s): Authors’ own sources

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**Figure 1.**
SmartPLS model analysis (authors own sources)

Source(s): Authors own sources
Similarly, H2 was supported, indicating a significant relationship between room lighting and student performance (LIG → SPER: $\beta = 0.236$, $t = 4.103$, $p = 0.000$). It was found that a proper improvement in lighting, by one standard deviation, leads to a corresponding increase in student performance by 0.236.

On the other hand, the study did not find a significant influence of temperature and chair design on student performance (TEM → SPER: $\beta = 0.082$, $t = 1.483$, $p = 0.146$) (CHA → SPER: $\beta = 0.048$, $t = 1.161$, $p = 0.256$). Therefore, H3 and H4 were not supported in this study.

Furthermore, H5 received support as motivation significantly influenced student performance (MOT → SPER: $\beta = 0.329$, $t = 5.285$, $p = 0.000$). A one standard deviation increase in motivation corresponds to an increase in student performance by 0.326.

Regarding student motivation, both noise and lighting were found to have a statistically significant impact, supporting H6 and H7 (NOI → MOT: $\beta = 0.249$, $t = 4.932$, $p = 0.000$) (LIG → MOT: $\beta = 0.386$, $t = 7.101$, $p = 0.000$). The findings indicate that effective noise control and improved lighting in the learning environment contribute to an increase in student motivation by 0.249 and 0.386, respectively. Additionally, conducive temperature control in the learning environment was found to increase student motivation by 0.196, providing support for H8 (TEM → MOT: $\beta = 0.196$, $t = 3.499$, $p = 0.000$). Lastly, the study found that an unfavourable chair design negatively influences student motivation to study, supporting H9 (CHA → MOT: $\beta = -0.080$, $t = 2.123$, $p = 0.034$).

**Mediator analysis**

The mediator analysis was conducted using 5,000 bootstrapped samples with a bias-corrected confidence level of 95%. This analysis was performed after establishing the significant relationship between motivation and student performance (H5), as shown in Table 3 (MOT → SPER: $\beta = 0.329$, $t = 5.285$, $p = 0.000$). The specific indirect effects of the mediator (motivation) were examined, and the results are presented in Table 4. Student motivation was found to be a statistically significant mediator between noise and student performance.
performance, as indicated by the t-value exceeding 1.96 and the p-value being less than 0.05
(Indirect effect = NOI → MOT → SPER: β = 0.081, t = 3.760, p = 0.000). Therefore, H10 is
supported, suggesting that motivation plays a partial mediating role in the relationship
between noise and student performance.

Similarly, motivation was found to be a statistically significant mediator between lighting
and student performance (Indirect effect = LIG → MOT → SPER: β = 0.126, t = 4.214,
p = 0.000). This finding supports H11, indicating that motivation partially mediates the
relationship between lighting and student performance. Furthermore, motivation was
identified as a significant mediator between temperature and student performance (Indirect
effect = TEM → MOT → SPER: β = 0.064, t = 2.812, p = 0.005). Hence, H12 is supported,
suggesting that motivation partially mediates the relationship between temperature and
student performance.

However, motivation was not found to mediate the relationship between the chair design
and student performance, as the p-value exceeded 0.05. Therefore, the findings do not support
H13, indicating that motivation does not play a mediating role in this relationship.

Overall, the results of the mediator analysis highlight the significant mediating effect of
motivation between noise, lighting, and temperature on student performance. These findings
suggest that motivation partially explains the relationship between these environmental
factors and student performance. However, the chair design does not indirectly affect student
performance through motivation.

**Coefficient of determination R²**

The coefficient of determination (adjusted $R^2$) indicates the proportion of variance in the dependent
variable that can be explained by the model’s independent variable(s). In this case, the coefficient of
determination for the motivation construct (MOT) is reported as 0.446, meaning that motivation
can account for 44.6% of the variance in the model (refer to Table 5). This suggests that motivation
is a significant contributor to understanding the variation in the dependent variable.

Similarly, the constructs related to student performance can explain 47.2% of the variance
(adjusted $R^2 = 0.472$). This indicates that factors included in the model, such as noise, room
lighting, room temperature, and chair design, collectively account for 47.2% of the variability
observed in student performance.

**Discussion**

The study’s results revealed that among the four factors considered – noise, room lighting,
room temperature, and chair design – only two of them, specifically noise (H1) and room
lighting (H2), had a statistically significant impact on students’ academic performance as
perceived by them. The other two factors, room temperature (H3) and chair design (H4), did
not exhibit any significant effect on students’ academic performance from the student
perspective. However, the study found a statistically significant relationship between
motivation and students’ academic performance (H5).

Indeed, similar to H1 (noise → academic performance) and H2 (room lighting → academic
performance), both of the variables (noise and room lighting) also showed statistical

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Adjusted $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation (MOV)</td>
<td>0.446</td>
</tr>
<tr>
<td>Student performance (SPER)</td>
<td>0.472</td>
</tr>
</tbody>
</table>

**Source(s):** Authors’ own sources
significance toward student motivation (H6 and H7). Surprisingly, although the analysis of H3 (room temperature → academic performance) and H4 (chair design → academic performance) reported no statistically significant relationship, the analysis of both variables (room temperature and chair design) toward motivation reported a statistically significant relationship (H8 and H9).

Moreover, the study’s examination of students’ personal perceptions of their potential academic performance in relation to physical ergonomics is particularly relevant given the significant impact of noise and lighting on the learning environment. Noise levels have been identified as a particularly influential factor, capable of disrupting concentration and cognitive processing, thereby posing significant challenges for students attempting to engage in their studies effectively. Whether stemming from external sources or originating within the classroom itself, excessive noise has been shown to impair information retention and hinder the ability to communicate effectively with instructors and peers. This notion is supported by previous studies, such as those conducted by Chere and Kirkham (2021) and Soltaninejad et al. (2021), which have highlighted the detrimental effects of noise on student learning outcomes and classroom dynamics.

Similarly, the role of lighting cannot be overstated, as it significantly impacts the visual environment and can affect students’ moods, energy levels, and overall well-being. Lighting conditions play a pivotal role in visual comfort and perception within educational settings. Inadequate or poorly controlled lighting can result in visual discomfort, eyestrain, and fatigue, all of which can significantly impact a student’s ability to read, write, and engage with educational materials effectively. Moreover, the quality of lighting has been shown to influence mood and alertness, thereby affecting motivation levels and the capacity to absorb new information. These findings are consistent with previous research conducted by Realyvásquez-Vargas et al. (2020), which have highlighted the profound impact of lighting quality on student well-being and academic performance. Recognising the critical role of lighting in creating optimal learning environments is essential for educators and administrators striving to promote student engagement and success.

However, the study found that room temperature (H3) and chair design (H4) were not statistically significant toward student performance directly, contradicting the findings of previous studies (Alani and Hawas, 2021; Realyvásquez-Vargas et al., 2020). The lack of statistical significance in the relationship between temperature, chair comfort, and student academic performance can be better understood by considering the significant individual differences in students’ preferences. Just as individuals have distinct tastes in food, fashion, or room climate, students exhibit unique comfort preferences. For instance, consider the contrast between Emma and David. Emma may excel in a cooler classroom environment, finding it invigorating for concentration, while she prefers a plush chair for added comfort. Conversely, David might achieve his best results in a slightly warmer setting, where he can relax and focus better, and he favours a sturdier chair for support. These varying preferences underscore the challenge of establishing a consistently and statistically significant impact on academic performance that uniformly applies to diverse students.

Although no direct relationship was reported between room temperature and student performance (H3), the mediator analysis unveiled an intriguing outcome. Further examination of the indirect effects of predictors through mediator analysis revealed that motivation mediates the relationship between noise (H10), room lighting (H11), and room temperature (H12) concerning students’ academic performance. Consequently, while students’ perceptions may not reveal a direct link between room temperature and academic performance, the impact may emerge indirectly through motivation. This indirect relationship mirrors findings related to noise and room lighting, suggesting that environmental factors influence students’ learning experiences by affecting their motivation levels. For instance, a comfortable temperature can enhance students’ focus and engagement,
positively impacting their motivation to learn. This suggests that while room temperature may not exert a direct influence on student’s academic achievements, it indirectly affects performance through its impact on motivation levels. This finding underscores the significance of environmental comfort in educational settings and highlights the role of motivation as a key determinant of student success. By understanding the indirect pathways through which environmental factors like room temperature influence student performance, educators and administrators can make informed decisions to optimise learning environments and enhance student motivation, ultimately fostering improved academic outcomes.

Additionally, previous research by Gumasing and Castro (2023) underscores the correlation between student motivation and enhanced academic performance, which supports the findings of this study. While motivation undoubtedly plays a pivotal role in shaping academic outcomes, it’s crucial to acknowledge the multifaceted nature of academic success. Motivation, as a complex construct, manifests differently across individuals, influenced by various factors such as personal goals, interests, and external circumstances. Therefore, understanding the nuances of motivation and its interplay with other determinants of academic success is essential for devising effective strategies to support students in their educational journey.

**Practical implication**
The study’s findings hold practical implications that can benefit both educators and students. By optimising the physical ergonomics of learning environments, educational institutions can create spaces that enhance students’ comfort and, consequently, their academic performance. Recognising the link between motivation and academic success, institutions can implement strategies to foster student motivation, leading to increased engagement and commitment to their studies. This, in turn, can result in higher retention rates, increased student satisfaction, and improved academic outcomes, thereby enhancing the institution’s reputation and competitiveness in the education market. Moreover, acknowledging the diverse preferences of students regarding physical ergonomics, institutions can consider offering flexible learning spaces that cater to individual needs and preferences, ultimately creating more inclusive and accommodating environments. Additionally, understanding the role of socioeconomic factors in shaping the relationship between physical ergonomics and motivation allows institutions to address the unique challenges faced by students from various backgrounds, promoting equity in education and contributing to positive social change.

**Theoretical implication**
The study’s findings introduce new insights into the research area by shedding light on previously unexplored aspects of physical ergonomics and its impact on academic performance from a student perception point of view. Specifically, it unveils the nuanced relationship between external factors such as noise, lighting, temperature, and chair quality and their influence on students’ educational outcomes. These findings challenge conventional understandings and provide a deeper understanding of the multifaceted dynamics at play within learning environments. Moreover, the research uncovers the mediating role of motivation in linking physical ergonomics to academic performance, presenting a novel perspective on the mechanisms driving student success. This novel finding highlights the intricate interplay between environmental factors and individual psychological processes, underscoring the importance of considering both aspects in educational interventions and policy decisions. Furthermore, the study’s recognition of diverse student preferences emphasises the need for personalised approaches to education, acknowledging that one-size-
fits-all solutions may not effectively address the varied needs of students. By highlighting the significance of tailored learning environments, the research opens new avenues for designing educational spaces that optimise student engagement and performance.

**Study limitation and future research direction**

The study’s limitations warrant critical consideration as they may impact the validity and generalisability of the findings. Firstly, the study looked into students’ personal perceptions of their potential academic performance, as the research is not experimental in nature. Future studies can conduct experimental research to evidently measure the outcome. Next, the reliance on an online survey with convenience sampling introduces inherent biases, potentially skewing the participant demographics and affecting the representativeness of the sample. To address this limitation, future research should consider employing probability sampling techniques to ensure a more diverse and representative sample, thus enhancing the external validity of the study’s findings. Furthermore, the study’s exclusive focus on Malaysian higher education institution students limits the generalisability of the findings to a broader student population. This narrow scope overlooks the potential differences in experiences and perceptions among students from various educational backgrounds and institutions. To address this limitation, future research should expand its participant pool to include students from different educational levels and institutions, allowing for a more comprehensive understanding of the relationship between physical ergonomics and student outcomes across diverse contexts.

Additionally, conducting comparative studies across higher education systems in different countries can offer valuable insights into the universality of the findings and the influence of cultural and institutional factors on student experiences. By exploring variations in physical ergonomics and their impact on student performance and motivation across different cultural contexts, researchers can enhance the external validity and applicability of their findings on a global scale. Moreover, future research endeavours could benefit from incorporating qualitative methods such as participant interviews to complement quantitative data collection. By delving deeper into students’ experiences, perceptions, and preferences regarding physical ergonomics, qualitative research can provide richer insights and a more nuanced understanding of the subject matter. This mixed-methods approach can strengthen the validity and robustness of the findings, offering a more comprehensive exploration of the complex interplay between physical ergonomics and student outcomes.

**Conclusion**

In conclusion, this study provides valuable insights into the complex relationship between physical ergonomics and students’ academic performance, primarily from the perspective of students’ personal perceptions of their potential academic outcomes. The data reveal the undeniable influence of noise and lighting on academic performance, while also highlighting the significant impact of temperature on motivated students’ performance. These findings emphasise the critical role that a student’s immediate environment plays in shaping their educational experience and outcomes.

Although this research is not experimental, it captures the nuanced views of students on how their learning environments affect their academic potential. The non-significant impact of certain factors, such as chair ergonomics, suggests that other personal perceptions or variables may be more pivotal in shaping academic success. Additionally, the study points out that students’ socioeconomic conditions can influence their perceptions of their learning environments and, consequently, their academic performance.

These insights provide a foundation for educational institutions to address the physical learning environment more holistically. By optimising noise and lighting levels and fostering
In sum, this research underlines the importance of tailoring learning spaces to accommodate the diverse needs of students, thereby promoting academic excellence. It also invites further research into the broader implications of these findings across different contexts, contributing to the advancement of education.

References


**Corresponding author**
Masliana Tamrin can be contacted at: masliana434@uitm.edu.my

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