ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VIII, August 2026

Assessment of Thermal Performance of Modular Wall Panels with Salt Hydrate PCMS in Selected Classrooms of Gusaling Villegas in Pamantasan NG Lungsod NG Maynila

[1]Aguilar, Zedrick P., [2]Glomar, Marc Nel G., [3]Icamina, Erron N., [4]Lai, Xaviel Wei Zhi., [5]Magaling, Rumil Angelo M., [6*]Odal, Algerico Jr S.

[1,2,3,4,5,6]Pamantasan ng Lungsod ng Maynila, Faculty Member

DOI: https://doi.org/10.51583/IJLTEMAS.2026.150800057

Received: 20 August 2026; Accepted: 25 August 2026; Published: 10 September 2026

ABSTRACT

Classroom overheating is an increasing concern in tropical urban environments, particularly in educational buildings where elevated indoor temperatures may affect thermal comfort and learning conditions. This study evaluated the thermal performance of modular wall panels integrated with salt hydrate phase change materials (PCMs) as a passive cooling intervention in selected classrooms of Gusaling Villegas (GV) at Pamantasan ng Lungsod ng Maynila. A quasi-experimental research design was employed using one classroom equipped with PCM-integrated wall panels as the test room and another classroom without PCM panels as the control room. Indoor temperature and relative humidity were monitored over six testing days. The PCM system utilized sodium sulfate decahydrate as the salt hydrate PCM, with polyethylene terephthalate (PET) bottles serving as the protective encapsulation material. Differential scanning calorimetry testing was also conducted to examine the thermal characteristics and repeatability of the PET casing material. The results showed that the PCM-equipped classroom consistently recorded lower temperatures than the control classroom. Mean temperature differences across the six testing days ranged from 0.14°C to 0.67°C, while the maximum observed peak-temperature reduction was 0.85°C. The largest average temperature reduction occurred under the hotter conditions observed on Day 5. Relative time-lag effects were inconsistent, with measurable delays observed on some testing days but no consistent delay across the entire monitoring period. Relative humidity was only marginally affected, with an overall average difference of approximately 0.98%. Statistical analysis showed that the temperature data were non-normally distributed; therefore, a Mann–Whitney U test was employed. The test indicated a statistically significant difference between the temperature distributions of the test and control rooms ($p < 0.05$), with the PCM-equipped room exhibiting a lower mean temperature. Despite the statistically significant difference, the magnitude of temperature reduction remained relatively small for practical thermal-comfort improvement. The findings indicate that PCM-integrated wall panels have measurable passive-cooling potential but require improved encapsulation, thermal conductivity, surface-area-to-volume ratio, placement, and experimental duration to maximize their effectiveness in existing educational buildings.

Keywords: phase change materials; salt hydrate PCM; passive cooling; thermal performance; classroom; thermal comfort; modular wall panels; sodium sulfate decahydrate

INTRODUCTION

In recent years, extreme heat event has increased, especially in the Philippines. According to Manalo et al. (2022), the minimum temperature in the Philippines has been observed to increase by about 0.25 °C per decade

specifically in urban areas. Metro Manila is one of the most vulnerable areas for heat hazards due to its dense urban environment, limited vegetation, and vast concrete regions, all these factors intensify the urban heat island effect, resulting in the city experiencing more extreme heat than nearby regions (Estoque et al., 2020). Urban residents, including those in major cities like Manila, are increasingly exposed to prolonged periods of extreme heat. Studies show that heat stress is already severe for most urban Filipinos, with population density strongly correlating with higher levels of perceived heat stress. This exposure is not only a matter of discomfort but also has significant implications for health, well-being, and productivity, especially in environments lacking adequate cooling or green spaces (Zander et al., 2018; Estoque et al., 2020). Intramuros, located in Manila, illustrates these challenges. Intramuros is a crowded urban area with few trees and many surfaces that easily absorb heat. The dense urban layout of Intramuros disrupts airflow and, together with heat absorbing materials like concrete and asphalt, traps warm, humid air and makes the area significantly hotter than its surroundings (Dela Torre, 2025). Such urban characteristics worsen the local temperatures and humidity, directly impacting educational institutions, one of them is the Pamantasan ng Lungsod ng Maynila (PLM). Unlike other private institutions, PLM is a state university which has limited resources for cooling systems, resulting in elevated indoor temperatures during extreme hot weather. These thermal conditions in educational settings can make the classrooms hotter and more uncomfortable, hindering students' and professors' ability to concentrate and perform effectively (Akkose et al., 2021; Lamberti et al., 2021) In fact, a survey conducted by the Alliance of Concerned Teachers-National Capital Region (ACT-NCR) found that 87 percent of teachers in Metro Manila believe that classroom overheating hinders the effectiveness of teaching and learning (Daanoy, 2024). Additionally, the Philippines already faces a severe education crisis that affects the future of the country's economy, and the main victims are the young students (Punongbayan, 2024). Some studies show different factors that affect the performance of the studies. According to Mushtaq and Khan (2012), there are factors that affect the student's performance, such as communication, proper guidance, family stress, and learning facilities. It shows that there is a positive relationship between learning facilities and student performance.

General Objective

The general objective of this study is to design and construct wall panels integrated with phase change materials (PCMs) and to evaluate their thermal performance when placed inside selected classrooms of Gusaling Villegas in Pamantasan ng Lungsod ng Maynila.

Specific Objectives

1. To collect indoor temperature and relative humidity data from selected classrooms in Gusaling Villegas.
2. To design and install PCM-integrated wall panels that fit within classroom spatial constraints.
3. To compare the thermal conditions of the selected classrooms with and without PCM walls panels.
4. To determine the reduction in temperature, Relative time lag effect, and relative humidity conditions achieved through the integration of the PCM wall panels.

METHODOLOGY

Research Design

This study aims to evaluate the effectiveness of the constructed modular wall panels integrated with PCMs in enhancing the thermal performance of selected classrooms in GV. This study employs a quantitative research method because it focuses on the numerical measurement and statistical evaluation of indoor environmental conditions. Temperature and relative humidity readings in the selected classrooms will be recorded at regular intervals and compiled into datasets. Since true experimental design in real-world settings is often not feasible due to constraints such as the inability to randomly assign subjects or environments, a quasi-experimental design will be utilized in this study. According to Harris et al. (2006), quasi-experimental studies allow for evaluation of interventions in real-world settings without randomization. This is done comparing a treatment group to a non-randomly selected control group, providing evidence of effect while maintaining practicality. Although the classrooms are not randomly selected, these types of experiments can still yield valid causal conclusions if appropriate statistical controls are applied and the design is carefully implemented (Shadish et al., 2008).

Research Population

This study was conducted at Pamantasan ng Lungsod ng Maynila, specifically within the engineering building, Gusaling Villegas (GV). The location was selected due to its accessibility and suitability for testing the thermal performance of classrooms, as the researchers are civil engineering students and have convenient access to the facilities in GV. Additionally, the corridors of GV receives direct sunlight for a significant portion of the day, while the other side of the corridor is closely bordered by another building, which minimizes air circulation. These factors provide practical and relevant choice for evaluating the effectiveness of the PCM walls in buffering heat.

Research Sampling

This study utilized purposive sampling to select two classrooms in Gusaling Villegas that can meet the specific conditions needed for determining the effectiveness of PCM-integrated wall panels to the selected classroom. Purposive sampling is appropriate because selection criteria for both classrooms must be strictly considered. The criteria will include similar dimensions, number and orientation of doors and windows, construction materials and finishes, exposure to sunlight, and outdoor environments. When two classrooms are decided, one will serve as the control room (without PCM walls) and other will serve as the test room (with PCM walls).

Data Gathering Instrumentation and Procedures

This study used calibrated measuring tools and monitoring devices to record the thermal performance of the classrooms. DHT22 Temperature and Humidity sensor modules purchased from Makerlab PH in Santa Cruz, Manila, were installed inside the classroom at various positions to continuously record temperature and humidity profiles. These data loggers allow long-duration monitoring, ensuring that subtle changes or fluctuations in thermal behavior are accurately captured. Prior to actual deployment, the sensors underwent a validation process to ensure accuracy and reliability. The DHT22 sensors were placed under the same environmental conditions to check for consistency in readings. This comparative approach allowed the researchers to identify any significant deviations among the sensors. A trial run was also conducted to observe sensor stability and performance over time before the start of the data gathering period.

Procedures

Selection of Classrooms in Gusaling Villegas (GV)

The selection of the classrooms used in the study was conducted based on the criteria established under the sampling procedure. The identified classrooms in GV were evaluated to determine the similarity of their physical characteristics to establish relatively homogeneous environmental conditions. This process was necessary to ensure that any observed variations in indoor temperature and relative humidity could be primarily attributed to the integration of the PCMs rather than pre-existing differences between the classrooms.

Sourcing and Testing of PET Bottles

Waste PET bottles were collected within the university premises from various designated waste bins and classrooms to serve as the casing material for the PCMs. The collection process was aligned with the researchers' class schedules. Only clean, undamaged, and uniformly sized bottles were selected for use. The retrieved bottles were inspected, rinsed, and air-dried before preparation. This method allowed the researchers to utilize readily available waste materials while maintaining consistency in the PCM containers, supporting both sustainability and standardization in the experimental setup. To ensure the suitability of the PET bottles as a storage for macro-encapsulation, the researchers conducted properties testing on the collected PET Bottles. This was determined through Differential Scanning Calorimetry (DSC) to provide further safety in packaging, Although the study of Tsironi et al. (2022) suggests that the typical melting point and glass transition temperature of PET bottles is at 267°C and 67°C to 80°C, respectively, further testing would ensure the actual values of thermal properties of PET bottles that will be used in the testing.

Figure 1: Instrument used for DSC analysis in NASAT Labs

Preparation of Salt Hydrates

The PCM selected is a salt hydrate, specifically sodium sulfate decahydrate ($Na_2SO_4 \cdot 10H_2O$), commonly known as Glauber's salt. This was prepared by hydrating anhydrous sodium sulfate (Na_2SO_4) through controlled mixing with distilled water to obtain the decahydrate form required for PCM applications.Sodium sulfate decahydrate was chosen as the PCM because of its relatively low cost and for its melting point at approximately 32°C, which is suitable for the local climatic condition and thermal regulation in classroom applications. To modify its thermal and physical properties, carboxymethyl cellulose (CMC) was added as a thickening agent to enhance mixture homogeneity and reduce phase segregation during repeated thermal cycling. Borax ($Na_2B_4O_7 \cdot 10H_2O$) was used as a nucleating agent to minimize supercooling and improve crystallization stability.

Figure 2: Schematic diagram of salt hydrate preparation

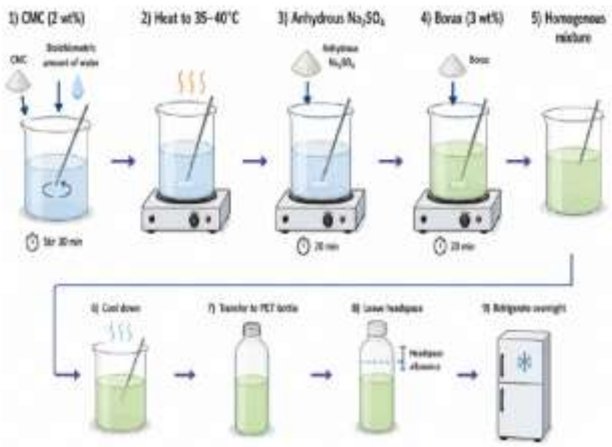
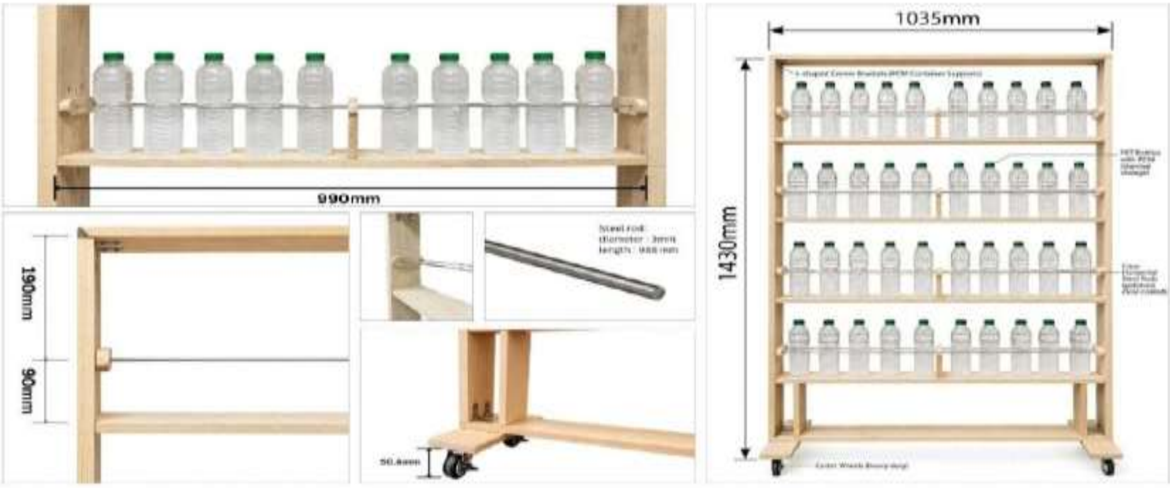


Figure 3: Actual images of the salt hydrate sample making process

Construction of Modular Wall Panels

The modular wall panels were fabricated and assembled in accordance with the dimensions of the selected classroom, ensuring compatibility with the existing layout and preserving its intended use. The wall panels were designed in a modular form so that they can be easily installed, removed, and maintained. Proper alignment and secure connections were ensured so that the panels can effectively house the PCM-filled bottles. The construction started with the fabrication of the main frame using palochina wood, a type of repurposed or reclaimed wood that is salvaged from old barns, factories and shipping crates. This type of wood was chosen because it is eco-friendly and much affordable compared to other types available in hardware stores, while still being strong enough for the structure. The wooden members were cut and assembled to form a rectangular frame. After completing the frame, horizontal layers were added with equal spacing between each level. These layers serve as the support for the PCM-filled bottles. Each layer was designed to house 10 bottles to maintain a uniform arrangement.

Figure 4: Detailed specifications of the modular wall panels



Classroom Setup for Testing

The PCM wall panels and the sensor modules were positioned properly inside the classroom for a more accurate assessment of the PCM walls' performance under realistic heat-gain scenarios. Table 5 below presents the experimental setup for each testing week. Monitoring period lasted from 8:00 AM to 4:00 PM for each day of testing.

Table 1: Experimental setup of PCM wall panels placement

	GV Room 206	***GV Room 207***
Day 1	Test	Control
Day 2	Control	Test
Day 3	Test	Control
Day 4	Control	Test
Day 5	Test	Control
Day 6	Control	Test

Data Collection and Analysis

The data collection was done in a consistent and repeatable way to compare the control room and test room. Indoor temperature and relative humidity were recorded simultaneously in both selected classrooms. This is done every 5 minutes, from 8:00 AM to 4:00 PM. The time frame and intervals ensure that the typical daily peak heat conditions are captured. All readings were recorded with timestamps, which were used to calculate the maximum and average temperatures for each day. The data collected were then analyzed through a comparison of the data recorded in both classrooms and plotted on a graph with respect to time.

ANALYSIS OF RESULTS

Laboratory Testing of PET Bottle Samples

NASAT Labs was endorsed by the Department of Science and Technology due to the temporary unavailability of testing equipment in their facility. To ensure the reliability and validity of the results, three separate samples taken from three similar PET bottles were analyzed.

Differential Scanning Calorimetry (DSC) Results

Table 2: Temperature Ranges and Enthalpy Values of Samples

SAMPLE ID		TEMPERATURE RANGE (°C) ONSET [a]	PEAK [b]	OFFSET [c]	ENTHALPY (J/g) [d]	Tg[e]
S01	S1	169.8	169.9	170.0	-	169.9
		238.7	249.0	254.3	22.7	-
		398.5	429.9	450.9	79.0	-
S02	S2	239.1	248.7	255.5	24.7	Non Observed
		425.5	431.5	474.9	83.5	
S03	S3	238.4	249.1	255.6	25.5	Non Observed
		410.7	422.1	446.3	82.5	

[a] ***Onset Temperature (°C)*** *the temperature at which the thermal event begins.*

[b] ***Peak Temperature (°C)*** *the temperature corresponding to the maximum rate of heat flow during the thermal event.*

[c] ***Offset Temperature (°C)*** *the temperature at which the thermal event ends.*

[d] ***Enthalpy (J/g)*** *the heat absorbed or released during the thermal event, normalized to sample mass.*

[e] ***Glass Transition (°C)*** *the temperature range where the material transitions from a rigid, glassy state to a soft, rubbery state, indicating increased molecular mobility without a phase change.*

The DSC results of the three samples exhibit highly consistent thermal behavior. The primary phase transition occurs at approximately 248–249 °C across all samples, with only minimal variation of less than 1 °C. This indicates excellent repeatability in the measured phase change temperature, suggesting that the material is homogeneous and that the experimental procedure is reliable. The close alignment of onset, peak, and offset temperatures further supports the uniformity of the material's thermal response. In terms of thermal energy storage, the enthalpy values associated with the primary transition are also closely grouped, ranging from 22.7 to 25.5 J/g. Although slight variations are observed, these differences are minimal and can be attributed to normal experimental factors such as small differences in sample mass and instrument sensitivity.

Figure 5: DSC result of PET bottle sample no. 1

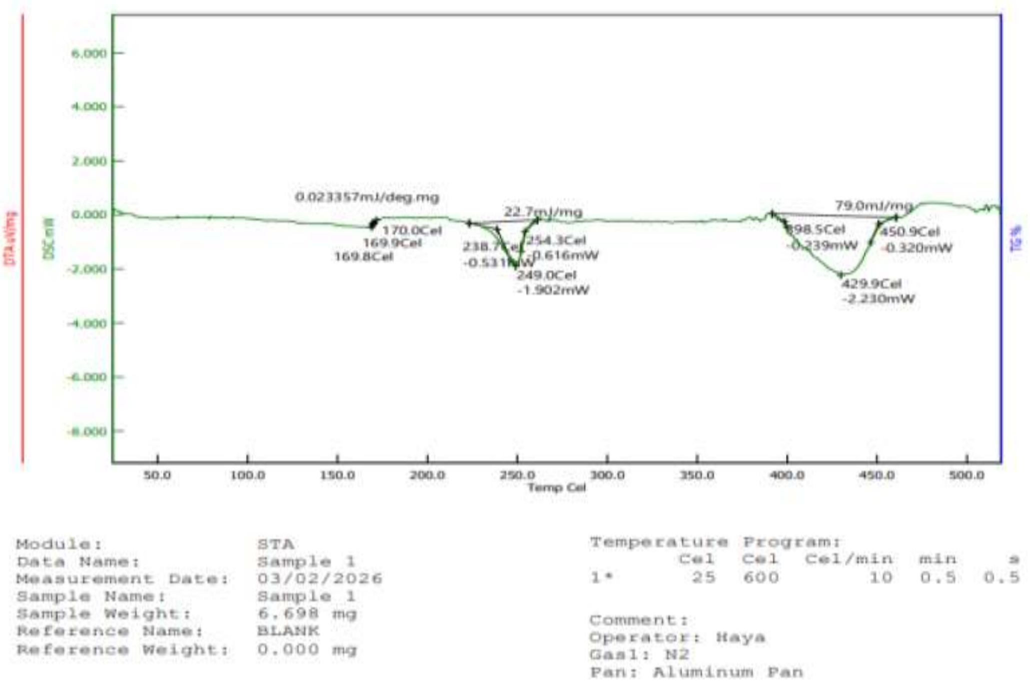


Figure 6: DSC result of PET bottle sample no. 2

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

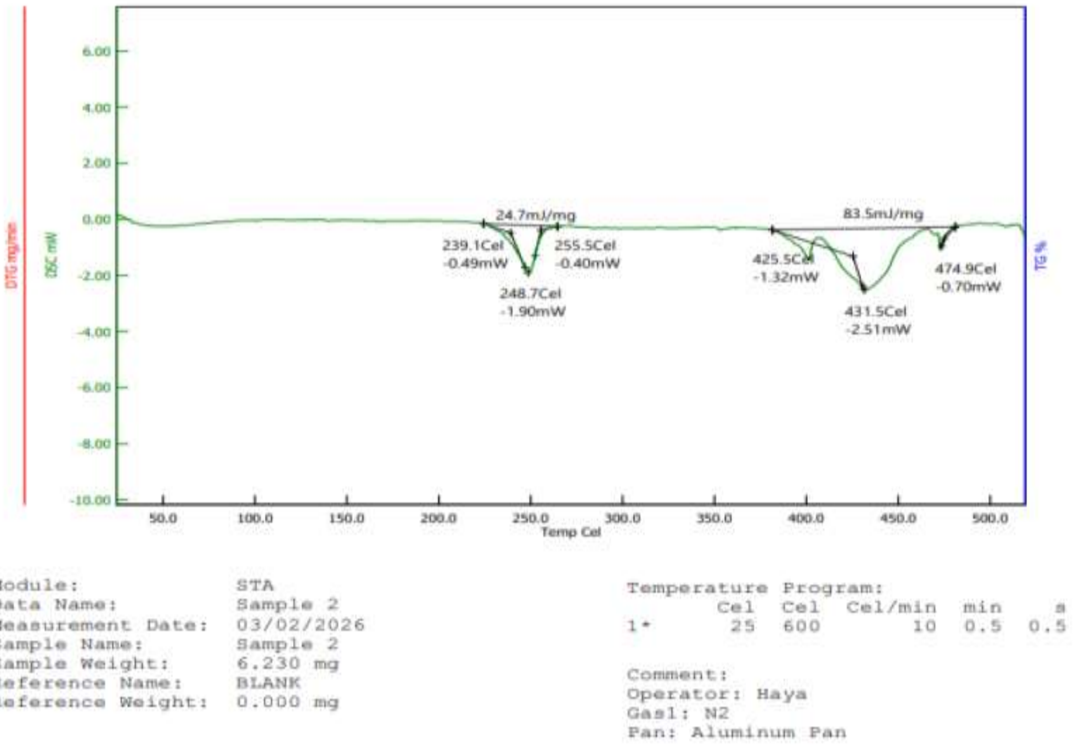
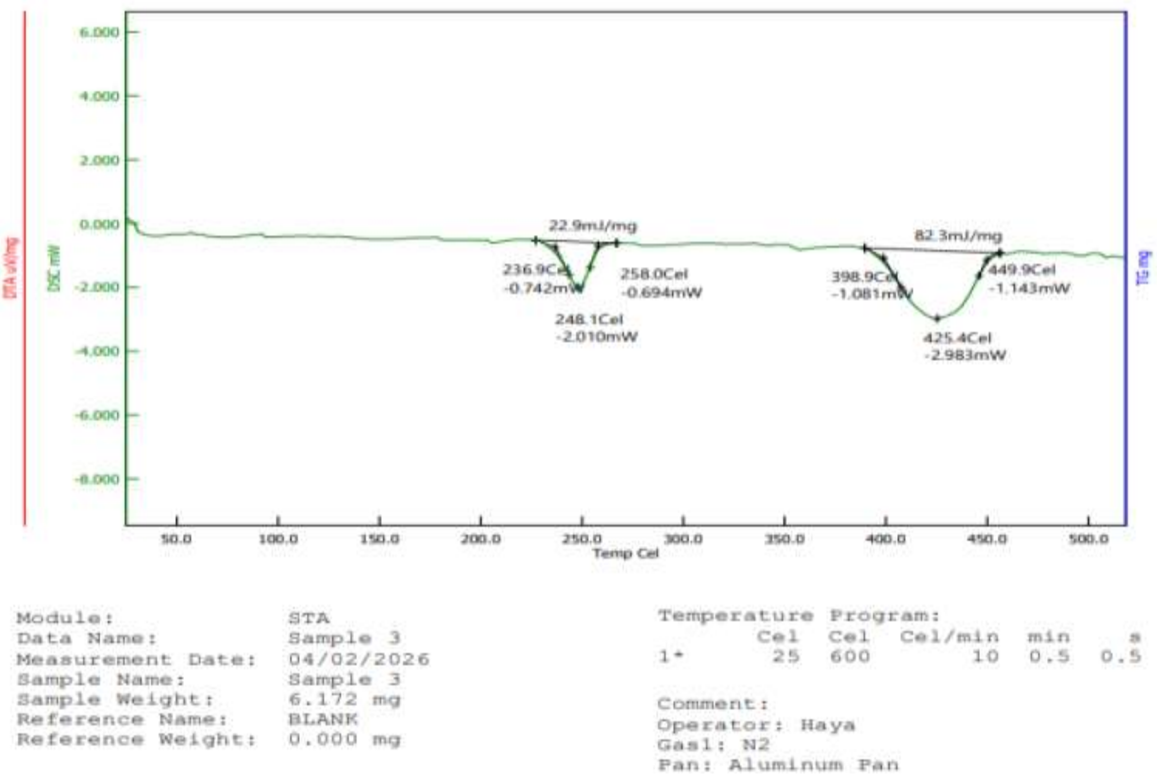


Figure 7: DSC result of PET bottle sample no. 3



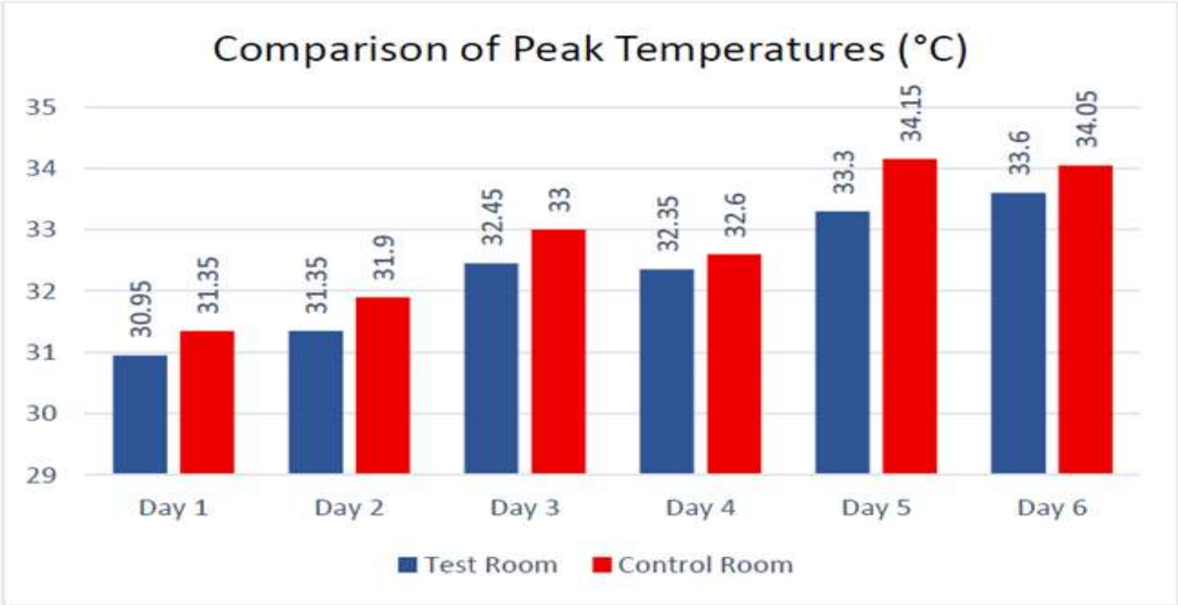
The DSC curves from all three trials exhibit similar shapes and peak positions, which concludes that the material demonstrates reliable and repeatable thermal performance. Overall, the results confirm that the tested material possesses stable and reproducible thermal properties. Furthermore, the absence of significant phase changes at lower temperatures indicates that the material will remain structurally stable during the typical operating range of most phase change materials.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

Recorded Temperature and Relative Humidity Profiles

Peak Temperature Reduction

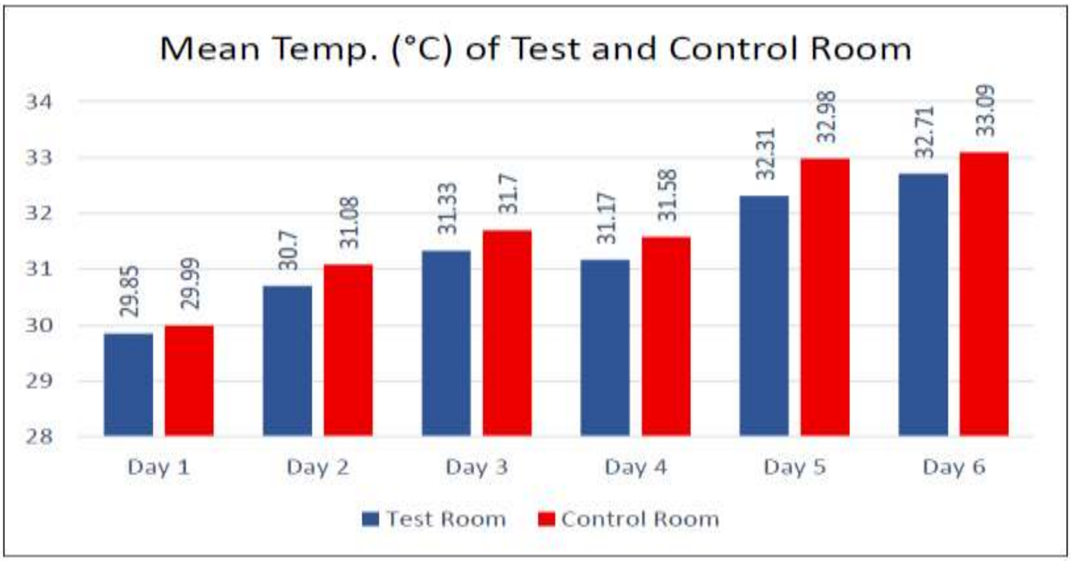
Figure 8: Comparison of peak temperatures of control and test room



The chart shows that the test room consistently recorded lower peak temperatures than the control room across all six days. The reduction was slight but consistent, ranging around 0.3°C to 0.85°C. This indicates that the PCM wall panels have successfully helped reduce peak heat levels but only to a minimal extent.

Comparison of Mean Classroom Temperature and Relative Humidity

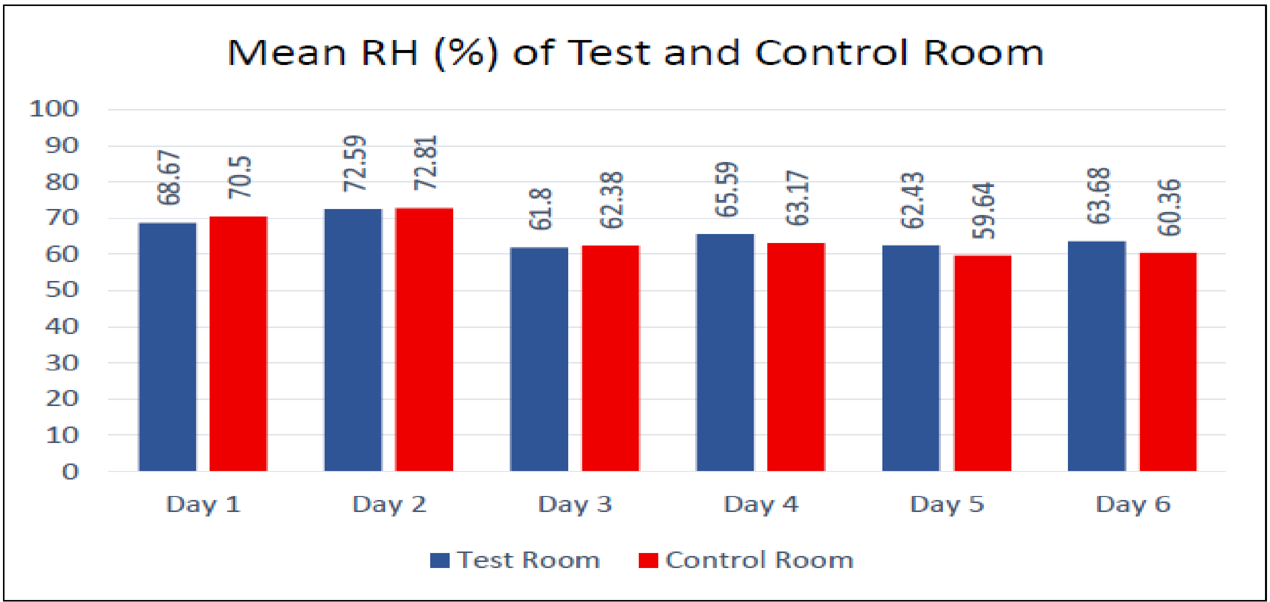
Figure 9: Mean Temperature



The graph shows a consistent pattern where the test room with PCM wall panels maintains slightly lower average temperatures compared to the control room across all six testing days. Although the differences are relatively small, they are consistently observed, suggesting that the PCM wall panels had some effect in reducing indoor heat. On Day 1, the difference is minimal at around 0.14°C, indicating only a very slight improvement in thermal conditions, but may be attributed to the weather conditions that day. From Day 2 to Day 6, the difference becomes more noticeable, ranging from approximately 0.30°C to 0.67°C, with the highest difference recorded on day 5. This trend suggested that the PCM wall panels tend to perform better under higher temperature conditions, although the level of improvement still remained limited. In addition, both rooms show an overall increase in temperature from Day 1 to Day 6, reflecting rising environmental heat during the testing period. Despite this trend, the test room consistently records lower temperatures than the control room. This indicates that the PCM wall panels can absorb heat and moderating temperature increase to some extent. However, the overall reduction in temperature is relatively small and may not be sufficient to produce a significant change in indoor thermal comfort.

Mean Relative Humidity

Figure 10: Comparison of mean RH values of control and test room



Monitoring relative humidity was an essential component of the study, as this could affect the occupant's thermal comfort and well-being. Experimental thermal comfort studies further indicate that moderate humidity levels (~40–60%) are associated with optimal comfort conditions (Ness, 2022). Higher humidity levels (>60%) are frequently associated with reduced thermal acceptability due to impaired evaporative cooling and increased sensations of warmth and stickiness. Based on the data gathered, the measured relative humidity for the control room was higher than the ideal range for thermal comfort of 40% to 60%. The lowest recorded relative humidity that was gathered is 55.65%, which is barely lower than the upper limit of acceptable range. This suggests the current relative humidity problem in the classrooms. The mean relative humidity of the control room throughout the testing was 64.81%, which is higher than the acceptable relative humidity. The highest recorded relative humidity was 78.65% in the controlled room, recorded on day 2 of testing, which is alarming. The average relative humidity on that day was 72.81%, implying the current relative humidity problems in the classrooms. The relative humidity in the test room did not cause any concerning effects. Although the average difference between the room's relative humidity was 0.98%, where the test room is slightly higher. The test room has a lower average relative humidity for the first three days of testing, and higher in the last three days of testing. The highest recorded average difference was 3.32% on day 6 of testing. This suggests that the PCMs did not contribute or cause any huge changes in relative humidity. The test rooms did not show any consistent or abrupt increase in moisture levels compared to the control room. The data did not show consistent higher relative humidity in the test room in the six days of data gathering. The fluctuations observed between the rooms remained relatively minor throughout the testing period.

Statistical Treatment of Recorded Data

The researchers used software for performing different statistical treatments. The software that was used is Jamovi and Statistical Package for the Social Sciences (SPSS) to compare for more accurate results. Each software is utilized for faster and more accurate processing of data.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

Test for Normality

In finding if there's a significant difference in the temperature of rooms with and without PCM, statistical tools will be used in the study. The normality test Shapiro-Wilk test was first executed. Shapiro-Wilk test was used to determine if the recorded temperature in both control and experimental rooms follows normal distribution curve. The results showed that both rooms' p-values are less than 0.05. Thus, the distribution of the temperature in both rooms is significantly different from the normal distribution curve. Suggesting that non-parametric test must be used in statistical analysis.

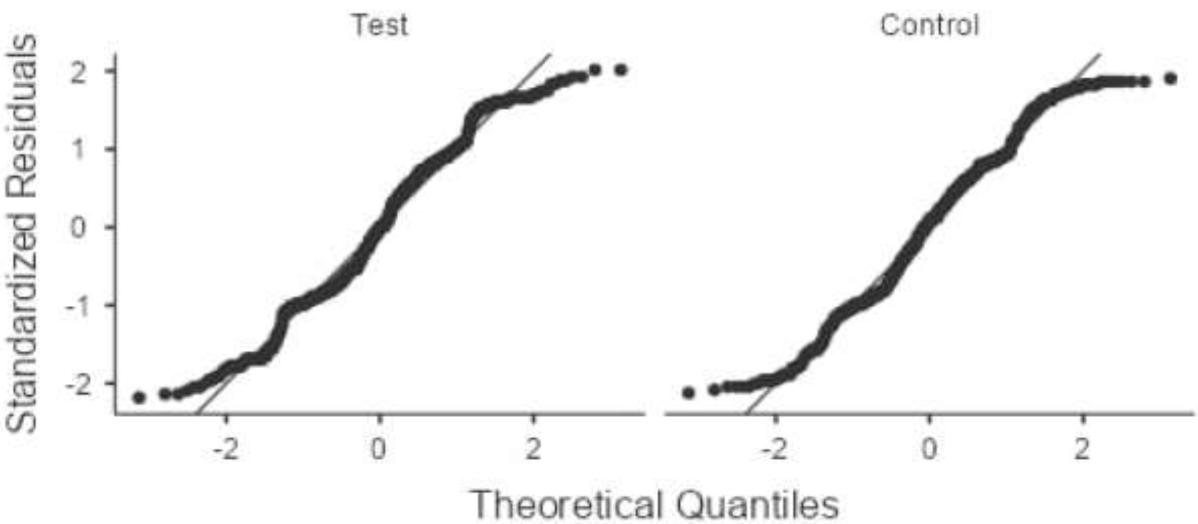
Table 3: Test for Normality of Data

	Test	*Control*
Shapiro- Wilk Statistic	0.973	0.977
Shapiro-Wilk p value	< 0.001	< 0.001
Kolmogorov-Smirnov Statistic	0.085	0.072
Kolmogorov-Smirnov p value	< 0.001	< 0.001

Moreover, a visual inspection of the temperature distribution was conducted to conclude that non-parametric test is needed. Histograms and Q-Q Plots were utilized to assess the data distribution characteristics of the experimental and control group.

The histogram for temperature data of experimental and control group shows a clear deviation from the standard bell-shaped required for normal distribution. Both datasets show different peaks bought by different data clusters. Data clusters are common at this setting due to colder morning temperatures and higher afternoon temperatures.

Figure 11: Q-Q Plot of Temperature Data of test and control group



The Q-Q plots further validate the non-normal nature of the data by comparing the observed standardized residuals against the theoretical quantiles of a normal distribution. In a normal distribution, the data points (represented by dots) should follow the straight diagonal reference line closely. However, in both experimental and test group, curves move further away from the line at the lower and upper extremities.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

Comparison of the Test and Control Room's Result

The next statistical tool to be utilized is the Mann-Whitney U-Test to determine if a significant difference exists between the temperature of each room. Mann-Whitney U-Test is an analog of the parametric Student T-Test. Mann-Whitney U-Test compares two independent groups that have data that does not have a normal distribution (Sundjaja et al., 2023). In a study of Naidoo et al. (2026), Mann-Whitney U-Test was utilized to assess if there is a significant difference between the temperature in rural and urban areas. Similarly, this study adopts the approach of Naidoo et al. (2026) by employing the Mann-Whitney U-Test to evaluate two independent groups, the experimental and control classrooms given that the temperature datasets do not follow normal distribution.

Table 4: Comparison of Mean Rank and Mean Temperature of Test and Control Rooms

	Test	*Control*	*Difference*
Mean Rank	529.65	636.35	-105.70
Mean Temperature	31.3	31.7	- 0.4°C
Maximum Temperature	33.6	34.1	- 0.5°C

The Mann-Whitney U-Test will evaluate if the difference in the room's temperature is unlikely due to chance or random sampling fluctuations. The result of the comparison shows that there is a significant difference between the room's temperature. The recorded p-value is less than 0.05 which rejects the null hypothesis, concluding that the one group ranks higher or lower than the other group.

CONCLUSION

This study contributes to the understanding of Phase Change Material (PCM) applications in improving the thermal performance of existing educational buildings, particularly in tropical climates. Unlike studies that focus on simulations or material-level analysis, this research provides an experimental evaluation of PCM-integrated wall panels under actual classroom conditions, allowing for a more realistic assessment of their performance in occupied spaces. The study only achieves an average indoor temperature difference of 0.4°C between the experimental and control rooms. These results might be perceived as low, yet the results are in line with the study of Attia et al. (2026). PCM performance varies across cases; PCM performs consistently with varying benefits. Attia et al. (2026) found that only a 1°C to 3°C peak indoor temperature reduction was made in eight full-scale, monitored buildings, which is not far from the 0.85°C recorded maximum temperature reduction. Firstly, the PCM-integrated wall panels were able to reduce indoor temperature in the test room compared to the control room. However, the level of temperature reduction remained relatively small. Additionally, the limited performance can be attributed to the low thermal conductivity caused by the use of plastic bottles as encapsulation material. Studies on polyethylene-based containers have shown that the naturally low thermal conductivity of plastic materials can reduce the responsiveness of latent heat storage systems during both charging and discharging cycles (Navarro et al., 2017, as cited in Rehman et al., 2023).Secondly, the effectiveness of the PCM panels increased under higher temperature conditions, suggesting that the material performs better when exposed to intense heat. As a result, more advanced encapsulation techniques such as microencapsulation are generally more effective in maximizing the thermal performance of PCM systems.

RECOMMENDATIONS

Based on the conclusion, PCM helped to lower the temperature, yet its performance could still be improved. Several factors that hinder PCM performance in lowering temperature must be addressed to fully utilize the benefits of using PCMs. Future researchers should explore the enhancement of PCM's thermal conductivity.

The use of additives that increase PCMs' thermal conductivity, such as expanded graphite, may be considered.

Other ways of macro-encapsulation may be reviewed to help PCM absorb heat energy from the environment. Most importantly, designing a storage that solves low surface area-to-volume ratios should be evaluated. Future researchers may explore the use of flatter, thinner casings or corrugated surfaces that maximize the contact area with the surrounding air. Finding a more targeted placement strategy within existing buildings should also be explored. A formal Design of Experiments (DOE) framework is recommended to systematically evaluate various placement configurations, enabling the identification of the optimal positioning for maximum thermal efficiency. Lastly, the researchers observed the existing problem with relative humidity. Naturally, temperature and relative humidity have an inverse relationship; the implementation of a hybrid system is recommended. Finding a hybrid system that would solve both problems of temperature and relative humidity will be beneficial for tropical countries like the Philippines.

REFERENCES

1. Akkose, G., Akgul, C. M., & Dino, I. G. (2021). Educational building retrofit under climate change and urban heat island effect. Journal of Building Engineering, 102294. https://doi.org/10.1016/j.jobe.2021.102294
2. Auliciems, A. & Szokolay, S.V. (2007) Thermal Comfort, 2nd ed.; Passive and Low Energy Architecture International in association with Department of Architecture, The University of Queensland: Brisbane, Australia,
3. Alam, T. E. (2015). Experimental Investigation of Encapsulated Phase Change Materials for Thermal Energy Storage. USF Tampa Graduate Theses and Dissertations. https://digitalcommons.usf.edu/etd/5632
4. Alassaad, K., Minto, J., & De Wilde, P. (2025). Enhancing Building Thermal Performance: A Review of Phase Change Material Integration. Energies. Enhancing Building Thermal Performance: A Review of Phase Change Material Integration.
5. Ayyagari, V., Shooshtari, A., & Ohadi, M. (2025). Glauber's Salt Composites for HVAC Applications: A Study on the Use of the T-History Method with a Modified Data Evaluation Methodology. Materials, 18(13), 2998. https://doi.org/10.3390/ma18132998
6. Baetens, R., Jelle, B. P., & Gustavsen, A. (2010). Phase change materials for building applications: A state-of-the-art review. Energy and Buildings, 42(9), 1361–1368. https://doi.org/10.1016/j.enbuild.2010.03.026
7. Bharathiraja, R., Ramkumar, T., Selvakumar, M., & Radhika, N. (2024). Thermal characteristics enhancement of Paraffin Wax Phase Change Material (PCM) for thermal storage applications. Renewable Energy, 222, 119986. https://doi.org/10.1016/j.renene.2024.119986
8. Chaichan, M. T., Kazem, H. A., Al-Waeli, A. H. A., & Sopian, K. (2021). Controlling the melting and solidification points temperature of PCMs on the performance and economic return of the water-cooled photovoltaic thermal system. Solar Energy, 224, 1344–1357. https://doi.org/10.1016/j.solener.2021.07.003
9. Cui, Y., Gulfam, R., Ishrat, Y., Iqbal, S., & Yao, F. (2024). Recent Progress of Phase Change Materials and Their Applications in Facility Agriculture and Related-Buildings—A Review. Buildings, 14(9), 2999–2999. https://doi.org/10.3390/buildings14092999
10. Cui, Y., Xie, J., Liu, J., Wang, J., & Chen, S. (2017). A review on phase change material application in building. Advances in Mechanical Engineering, 9(6), 168781401770082. https://doi.org/10.1177/1687814017700828
11. Daanoy, S. (2024, April 1). 87% of Metro Manila teachers say classroom heat hinders effective teaching, learning — survey. Manila Bulletin. https://mb.com.ph/2024/4/1/87-of-metro-manila-teachers-say-classroom-heat-hinders-effective-teaching-learning-survey
12. Duan, R., Wang, J., & Zhang, A. (2024). Analysis of thermal stability and enthalpy in SSD systems with various thickening agents. Journal of Physics: Conference Series, 2842(1), 012033. https://doi.org/10.1088/1742-6596/2842/1/012033
13. Estoque, R. C., Ooba, M., Seposo, X. T., Togawa, T., Hijioka, Y., Takahashi, K., & Nakamura, S. (2020). Heat health risk assessment in Philippine cities using remotely sensed data and social-

ecological indicators. Nature Communications, 11(1), 1581.https://doi.org/10.1038/s41467-020-15218-8

14. Guarnieri, G., Olivieri, B., Senna, G., & Vianello, A. (2023). Relative Humidity and Its Impact on the Immune System and Infections. International Journal of Molecular Sciences, 24(11), 9456. https://doi.org/10.3390/ijms24119456
15. Faghih, N., Mahdieh Abravesh, M., & Heidari, S. (2023). Investigation of effective parameters on thermal performance of multilayered glazing units integrated with Phase Change Material. https://doi.org/10.13140/RG.2.2.21360.02561
16. Harris, A. D., McGregor, J. C., Perencevich, E. N., Furuno, J. P., Zhu, J., Peterson, D. E., & Finkelstein, J. (2006). The Use and Interpretation of Quasi-Experimental Studies in Medical Informatics. Journal of the American Medical Informatics Association, 13(1), 16–23. https://doi.org/10.1197/jamia.m1749
17. He, S., Zhao, J., Ouyang, D., & Chen, M. (2025). Leakage-Proof and High-Conductivity Composite Phase Change Material Using Low-Melting-Point-Alloy-Encapsulated Copper Foam/Paraffin for Superior Thermal Homogeneity in Lithium-Ion Battery Modules. Materials, 18(19), 4604. https://doi.org/10.3390/ma18194604
18. Hirschey, J., Gluesenkamp, K., Mallow, A., & Graham, S. (2018). Purdue ePubs Review of Inorganic Salt Hydrates with Phase Change Temperature in Range of 5 to 60°C and Material Cost Comparison with Common Waxes. https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1319&context=ihpbc
19. Huet, E. E. (2016). Experimenting with refrigerated margarine as phase change material and zeolite as desiccant for temperature and humidity control in Philippine archives. Journal of Philippine Librarianship, 36, pp. 1-14. https://journals.upd.edu.ph/index.php/jpl/article/view/5942.
20. Jin, X., Xu, X., Zhang, X., & Yin, Y. (2014). Determination of the PCM melting temperature range using DSC. Thermochimica Acta, 595, 17–21. https://doi.org/10.1016/j.tca.2014.09.004
21. Jobli, M. I., Yao, R., Luo, Z., Shahrestani, M., Li, N. and Liu, H. (2019) Numerical and experimental studies of a capillarytube embedded PCM component for improving indoor thermal environment. Applied Thermal Engineering, 148. pp. 466477. https://doi.org/10.1016/j.applthermaleng.2018.10.041
22. Naidoo, N. (2020). Classroom temperatures in urban and rural classrooms: disparities that hinder a just energy transition and opportunities for interventions. The Pan African Medical Journal, 53(98). https://doi.org/10.11604/pamj.2026.53.98.49674.