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NeMTSS Research Brief

Optimal Classroom Learning Environment

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Optimal Classroom Learning Environment: An NeMTSS Research Brief

Key Points:

- Humans can acclimate to the climate in which they are living. As such, optimal temperatures for working and learning appear to vary among various geographical locations and climates.

- Research examining classrooms in moderate climates, similar to that of Nebraska, support the United States Department of Labor's recommended workplace temperatures of 68-76°F, with most research supporting temperatures at the lower end of that range.

- Children appear to perceive comfort of indoor temperature differently from adults, and thus student, more than staff, perception of temperatures should be taken into consideration when classroom and school temperatures are adjusted.

- Other factors (e.g., ventilation, odor, noise, and amenities) of physical classroom learning environment have been examined and found to be equally, and sometimes more, essential than temperature of classrooms.

Research Overview

Many factors must be considered when working to establish an optimal learning environment for students. Classroom environments encompass physical, psychological, and academic factors influencing student participation, motivation, and ability to learn. The current research brief focuses on the importance of the physical learning environment, with an emphasis on the temperature of classrooms, and how these factors can impact student outcomes.

It is well documented that thermal discomfort, whether caused by high or low temperatures, can have a negative impact on student learning and performance. Previous studies have found that student perceptions of the conditions of the classroom physical learning environment had a great impact on their learning and motivation, personal behavior, school attendance, and reported satisfaction of courses (Asiyai, 2014; Han et al., 2018). In addition to temperature (i.e., heating and air conditioning), ventilation, odor, cleanliness of frequently used surfaces, acoustics and noise, room layout, furniture, and electronic and amenities, have all been found to be important factors related to the physical environment of educational spaces (Haverinen-Shaughnessy et al., 2015; Yang et al., 2013; Han et al. 2019). These findings support the notion that these factors can be adjusted to improve the health and academic performance of students. However, findings have been inconsistent in identifying which of these factors are the most salient when it comes to the impacts on student outcomes. One study by Pitehnoee et al. (2020) examined symbolic features (e.g., posters and educational materials) compared to structural features (e.g., lighting, acoustics, seating, and thermal comfort) and found that symbolic features have been particularly important for younger students, as elementary students have been shown to pay particular attention to these details above and beyond structural features (Pitehnoee et al., 2020).

In addition to the impact on academic success, the temperature of a classroom has been shown to be related to health factors, including the number of absences of students and the number of visits to school-based health services (Simons et al., 2010; Mendell et al., 2013; Plott et al., 2021). Specifically, the article by Plott et al. (2021) examined students in kindergarten

through 8th grade in United States schools. They found that indoor temperatures in examin schools ranged from 48-100.6°F throughout data collection, with over 50% of recorded temperatures being out of the United States Department of Labor's recommended temperatures of 68-76°F (United States Department of Labor, n.d.). When temperatures were ten degrees above baseline (75°F), there was a 53% increase of asthma-related visits to the school-based health center, clearly demonstrating the potential negative impacts high temperatures in classrooms can have on student health. The focus on students who have asthma is especially relevant, as Low-income and students from racial and ethnic minority groups have disproportionately higher rates of asthma and are more likely to attend schools with poor infrastructure that cannot always attend to high temperatures in classrooms (Plott et al., 2021). Therefore, considering the impacts of temperature in the learning environment is a matter of student academic success, physical health, and educational equity.

Measuring Optimal Temperature

Examining the optimal temperatures for workplace productivity and learning in educational settings is not new to research. The American society of heating, refrigerating and air-conditioning Engineers (ASHRAE) and other international organizations have worked to define acceptability rates for temperatures in public places. ASHRAE specifically considers acceptance rates to be the temperatures when 80-90% of individuals in a given space would rate an indoor temperature as acceptable (American Society of Heating, Refrigerating and Air Conditioning Engineers, 2013). Another organization, the International Standards Organization (ISO) allows for clothing to be taken into consideration, emphasizing the importance of the natural climate and human behavior when considering the impact of temperature (Jiang, 2021). It also points to the importance of examining student perceptions of the temperature, as student perception might be different from the assumed preferred temperatures.

It is also important to consider the fact that many studies examining classroom temperature have been conducted in laboratories, as it is difficult to maintain control in studies in the naturalistic environment. In the study by Jiang et al., (2018), 12 students who lived in northwestern China, where the climate is cooler, were asked to participate in cognitive tasks in various temperatures. Specifically, they participated in attention perception, comprehension, and deduction tasks. Results demonstrated that the optimal performance was found for 14 degrees Celsius (57.2°F). However, this study and similar studies conducted in labs, fail to incorporate human behavior that may be more realistic in natural environments.

Recommended Temperatures

There is a significant amount of research examining the impact of the physical environment on workplace productivity and learning in schools and universities. It is important to consider how different environments may be impacted by a multitude of factors. When we examine research from various geographical locations, individuals are more or less accustomed to the wide variety of climate. We see that when individuals from colder geographical locations are examined, their optimal temperatures are much lower than their tropical counterparts. For example, the study by Jiang et al. (2018) took place in northwestern China, where the climate is cooler. Results demonstrated that the optimal performance in cognitive tasks (attention, comprehension, deduction) was found to be 14 degrees Celsius (57.2°F). Another study by Porras-Salazar (2018) examined optimal temperatures for 11-year-old children in Costa Rica and found that these children were showing optimal performance of logical reasoning and reading comprehension at about 25 degrees Celsius (77°F), as they were tropically acclimated. These results demonstrate the importance of acclimation to climate when measuring optimal

indoor temperatures and a need to focus attention on research examining similar environments when applying research on optimal temperature to practical use.

Not only are students and teachers often acclimated to their climate, but they have the ability to compensate for non-optimal temperatures. A study done by Aghniaey et al. (2019) aimed to explore methods for minimizing energy consumption while maintaining occupant thermal comfort during conditions that would normally be considered as non-optimal. This study found that the thermal comfort dropped below 80% (the common acceptability rate) when the temperature went above 24.5 degrees Celsius (76.1°F). However, the same study showed that individuals who were participating in adaptive behaviors to minimize thermal discomfort (e.g., changing clothing level or having a drink) did not considerably change with room temperature, which was hypothesized to be due to students not having options for adaptive behaviors (e.g., did not bring a water bottle or layered clothing, or no ability to turn on a fan).

In a study by Barbic et al. (2019), University students from the United Kingdom had their cognitive performance assessed over two academic days, when temperatures of their classrooms changed. When temperatures increased by 4 degrees Celsius, there was a reduction in students' global cognitive performance, which was associated with cardiac sympathetic over-activity. This means that more students were endorsing thermal discomfort on day 2, when temperatures were 26.2 +/-1 degrees Celsius (79.16°F) compared to 22.4+/-1 degrees Celsius (72.32°F), indicating a preference toward a cooler learning environment.

In a study by Haverinen-Shaughnessy (2015), indoor environmental quality (IEQ), students' performance, absenteeism, and health data were examined for 70 schools in southwestern US, over two academic years. IEQ included temperature, relative humidity, carbon dioxide, and settled dust. They found that there were significant correlations between the percentages of students scoring satisfactory in math and reading and both indoor temperature and ventilation rates. Specifically, lower temperatures and higher ventilation rates were associated with higher math and reading scores (Haverinen-Shaughnessy, 2015). This is consistent with previous studies that have shown high room temperatures increase fatigue and reduce concentration, academic performance, and learning for students (Haverinen-Shaughnessy, et al., 2012; Melikov et al., 2013).

Another study by Haverinen-Shaughnessy & Shaughnessy (2015) found that maintaining adequate ventilation and thermal comfort in classrooms could significantly improve academic achievement of students, specifically examining effects on math, reading, and science scores. They found that when temperatures are in a range of 20-25 degrees Celsius, average math scores would increase by up to eleven points as ventilation increased and 12-13 points for every 1 degree Celsius lowered, indicating the optimal temperature for students in southwestern US would be between 68-77°F, with 68°F being the optimal temperature for this sample (Haverinen-Shaughnessy & Shaughnessy, 2015). However, of note, this study is limited by the fact that it only examined students from one grade level, school district, state, and climate, and thus it is difficult to generalize this data broadly.

A metanalysis by Wargocki et al. (2019) examined 18 studies that looked at the relationship between classroom temperature and children's performance in school. These studies specifically examined samples from moderate climates. The results showed that the performance of psychological tests and school tasks can be expected to increase on average of 20% if classroom temperatures are lowered from 30 degrees Celsius to 20 degrees Celsius and, further, the temperature for optimal performance is lower than 22 degrees Celsius (71.6°F) for temperate climates. This metanalysis also shows that the relationship of temperature and optimal performance for schoolwork is lower than optimal temperature for performance of office work, consistent with the idea that children have different thresholds of tolerance compared to adults. However, overall, The United States department of labor recommends

indoor temperatures be maintained between 68-76°F. (United States Department of Labor, n.d.), which is consistent with the majority of reported findings in this brief. Overall, students can acclimate to the room temperature, if in this given range, but slightly cooler or neutral (i.e., perceived as neither warm or cold) temperatures have been shown to be preferred by students and shown to have the best outcomes related to academic tasks.

Age Considerations

Overall, it is agreed upon that an optimal temperature range should exist for performance, but most research has focused on adult samples, which does not necessarily translate to children. For example, psychological and physical maturity can impact how individuals respond to changes in temperature. Children have poorer self-regulation abilities and may not be able to regulate themselves as effectively when it comes to temperature change (Jiang et al., 2018). This was shown to be consistent with a study by Montazami et al. (2017), which found that children's threshold comfort temperatures are at least 3 degrees Celsius lower than adults' during summer weather in a United Kingdom primary school classroom. The Montazami article also pointed to the importance of teacher behavior on student temperature satisfaction, as when students are able to express concerns about the temperature, and teachers can change it, the class overall can be more satisfied with the temperature and ready to learn (Montazami et al., 2017). Other findings have also shown that, compared to adults, young learners are more affected by the physical learning environment (Choi et al., 2014; Maxwell & Chmielewski, 2008).

Conclusion and Practical Implications

Not only is it important for student academic success, but physical environment needs to be considered to support physical and psychological wellbeing for students and educators in school buildings. Although one cannot pinpoint a perfect optimal temperature for educational purposes, it would be fair to assume that temperatures falling in the lower end of the United States Department of Labor recommended temperatures of 68-76°F, would be related to positive academic success and wellbeing of students. When these temperatures are not possible, it can also help for educators to encourage students to participate in thermal adaptive behaviors to maintain thermal comfort. Examined research points to optimal temperatures for learning, both for students and for educators. As one takes these factors into consideration, it is also imperative to consider additional factors that influence the physical learning environment when it comes to K-12 students.

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