The Importance of Thermal Comfort in the Classroom

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Abstract

This paper describes a study on the importance of thermal comfort in the classroom. Using the principles of Maslow's Hierarchy of needs, a teacher must be aware of the temperature of a classroom to ensure that the students are not more focused on their discomfort because of the classroom temperature than on the teacher's lessons. Temperatures were recorded in actual classrooms, and students were asked about their thermal comfort to determine if the temperature in the classroom actually did impact the ability of students to focus in the classroom. Lastly, this paper describes some techniques to improve the thermal comfort level of the classroom.

Maslow's Hierarchy of Needs

In order to be a successful teacher, it is critical to accept that each of your students learn in a different and distinct manner. Students are independently influenced by personal upbringing, beliefs, interests, etc. and as a result, learn at varying rates and levels. One helpful method to analyze and identify key traits and features in students is Maslow's Hierarchy of Needs. Maslow developed a theory of individuals' needs that has influenced a number of fields, to include education. Maslow's work is important to help teachers understand the basic needs students require to learn as well as provide a framework for higher level success.

Maslow's Hierarchy of Needs consists of five basic levels. As a rule, it is impossible for an individual to go from one level of need to another without having those initial needs met. For example, a student will never consider the Needs for Esteem level in Maslow's Hierarchy unless their Physiological Needs, Safety Needs and Needs of Love, Affection and Belongingness have already been satisfied. A brief description of Maslow's five basic levels is listed below:

1. Physiological Needs: These are biological needs. They consist of needs for oxygen, food, water, and a relatively constant body temperature. They are the

strongest needs because if a person were deprived of all needs, the physiological ones would come first in the person's search for satisfaction.

2. Safety Needs: When all physiological needs are satisfied and are no longer controlling thoughts and behaviors, the needs for security can become active. Adults have little awareness of their security needs except in times of emergency or periods of disorganization in the social structure.

3. Needs of Love, Affection and Belongingness: When the needs for safety and for physiological well-being are satisfied, the next class of needs for love, affection and belongingness can emerge. Maslow states that people seek to overcome feelings of loneliness and alienation. This involves both giving and receiving love, affection and the sense of belonging.

4. Needs for Esteem: When the first three classes of needs are satisfied, the needs for esteem can become dominant. These involve needs for both self-esteem and for the esteem a person gets from others. Humans have a need for a stable, firmly based, high level of self-respect, and respect from others.

5. Needs for Self-Actualization: When all of the foregoing needs are satisfied, then and only then are the needs for self-actualization activated. Maslow describes self-actualization as a person's need to be and do that which the person was “born to do." If a person is hungry, unsafe, not loved or accepted, or lacking self-esteem, it is very easy to know what the person is restless about. It is not always clear what a person wants when there is a need for self-actualization. (1)

Maslow believes that individuals are constantly trying to achieve the ultimate goal of self-actualization. He also believes that the only reason people would not pursue self-actualization is education. As a result of this belief, Maslow offers a list of ten points he claims educators should follow in their interactions with students. Maslow states that education should not use its normal “person-stunting tactics,” rather it should use “person-growing approaches” to develop their students. (1)

Maslow’s Hierarchy of Needs applies to thermal comfort in the classroom in a direct way. If a student’s basic physiological needs are not met, the likelihood of him or her considering any subsequent needs is lower than if those basic needs were initially

met. Maslow stresses that in order for an individual to pursue self-actualization, all of their prior needs must be realized before an individual can continue to progress. As it relates to education, it is critical for educators to assure basic needs physiological and safety needs are in place, if not, the “person-growing approaches” Maslow suggests cannot be considered.

Thermal Comfort

Thermal comfort has been discussed in various capacities since the early 1930s. Thermal comfort is defined as the perceived satisfaction an individual has with his or her respective environment. Thermal comfort has become a larger issue in the last couple of decades due to the large consumption of natural resources expended by buildings trying to meet some acceptable standard of comfort. (2) Furthermore, Nicol provides three critical reasons for understanding the importance of thermal comfort: i) to provide a satisfactory condition for people, ii) to control energy consumption and iii) to suggest and set standards. (3) As a result of this new information, leaders must constantly struggle between efficiently managing resources and helping people achieve a proper level of thermal comfort.

Our current understanding of thermal control has evolved from studies as far back as the 1890s. In each of these studies, individuals were monitored in a variety of environments, and as data points were collected, it became evident that thermal comfort was a significant factor in their comfort. Furthermore, thermal comfort has shown impacts on the brain’s ability to perform basic functions as well as affect the body’s ability to efficiently regulate temperature. (2) Figure 1 shows a list of studies that were related to the field of thermal comfort:

Year	Index
1897	Theory of heat transfer
1905	Wet bulb temperature (Tw)
1914	Katathermometer
1923	Effective temperature (ET)
1929	Equivalent temperature (Teq)
1932	Corrected effective temperature (CET)
1937	Operative temperature (Top)

1945	Thermal acceptance ratio (TAR)
1947	Predicted 4-h sweat rate (P4SR)
1948	Resultant temperature (RT)
1955	Heat stress index (HSI)
1957	Wet bulb globe temperature (WBGT)
1957	Oxford index (WD)
1957	Discomfort index (DI)
1958	Thermal strain index (TSI)
1960	Cumulative discomfort index (CumDI)
1962	Index of thermal stress (ITS)
1966	Heat strain index (corrected) (HSI)
1966	Prediction of heart rate (HR)
1970	Predicted mean vote (PMV)
1971	New effective temperature (ETn)
1971	Wet globe temperature (WGT)
1971	Humid operative temperature
1972	Predicted body core temperature
1972	Skin wettedness
1973	Standard effective temperature (SET)
1973	Predicted heart rate
1986	Predicted mean vote (modified) (PMVn)
1999	Modified discomfort index (MDI)
1999	Physiological equivalent temperature (PET)
2001	Environmental stress index (ESI)
2001	Universal thermal climate index (UTCI)
2005	Wet bulb dry temperature (WBDT)

Figure 1: Thermal Comfort Studies

Thermal comfort as it relates to this project can be more specifically described as the affects of temperature and humidity on the students in classroom. In a classroom, if a student feels too hot or too cold, the student does not have his or her basic physiological needs being met. Most teachers have seen the impact of when a class is much too warm; students begin to become much more distracted as they begin to fan themselves or wipe the sweat off of their forehead. Other students tend to fall asleep more easily in a classroom that is too warm. In a classroom environment, the thermal comfort of a classroom can negatively impact a student's ability to learn.

The most significant and detrimental effects temperature and humidity can have in a particular environment appear in the form of bacteria or mold. Although, these two outcomes were not specifically observed during this project, they are still potential threats that leaders should consider when discussing the impacts of temperature and humidity in the classroom. For example, a study of classrooms in Florida showed that allergy symptoms and complaints of

being sick were related to a high level of mold found in the buildings. This just reemphasizes the need for leaders to be concerned about the possible effects of humidity, and if students are feeling the impact of poor air quality or are concerned about their health, their physiological needs are going to be more important than trying to learn in the classroom. (4)

As leaders decide how to consider thermal comfort within their buildings and organizations, a common question that occurs is “What are the ideal conditions [with respect to temperature and humidity] I should achieve in my classrooms and offices?” Although this question has various answers depending on location, the ideal settings in a classroom are a moderate temperature between 68 degrees and 74 degrees Fahrenheit and a moderate humidity level between 40 and 70 percent. (4) Various studies have shown that students and office workers will perform mental tasks at a higher level when these two conditions are present.

Data Logging

Accurate and reliable data was necessary in order to understand the impacts of thermal comfort in office buildings and classrooms. Onset HOBO Data Loggers were selected to perform the data collection. HOBO Data Loggers are an integral part in modern day research providing an accurate picture of the surrounding environment and all of its variability. HOBO Data Loggers were designed to capture and record weather and climatic conditions that are constantly changing. (5)

HOBO Data Loggers have been used in a variety of research in order to capture numerous readings. For example, HOBO Data Loggers have been used to: “i) Perform ecological studies that provide a full, detailed picture of habitat conditions, ii) Conduct agricultural research that reveals issues and opportunities for improving yields, iii) Set up animal science studies that reveal the impact of climate conditions on species, iv) Perform soil studies to better understand the effects of climate on soil quality and v) Gather essential data for more effective stormwater management.” (5) In addition to a diverse portfolio of research areas and subjects, HOBO Data Loggers are easily purchased anywhere in the United States, they are some of the most reliable and accurate data loggers on the market today and they are extremely affordable and simple to install and use. (5) This project used HOBO Data Loggers by placing them in classrooms and then downloading the temperature and humidity data that was recorded for each classroom location.

Classroom Case Studies

Because of the historic nature of most of the buildings at the United States Military Academy at West Point, New York, there are often classrooms and offices that are not within the normal comfort zone. In this study, classrooms and offices in two buildings were measured: Thayer Hall and Mahan Hall. Recognizing the importance of the accurate data measurements, various rooms were selected throughout Thayer Hall and Mahan Hall in order to try and understand how thermal comfort influenced each of the locations. HOBO Data Loggers were specifically placed in rooms were occupants had expressed a concern for the temperature and/or humidity that existed in each of the rooms. HOBO Data Loggers were strategically placed in each of the rooms in order to record temperature and humidity readings.

Thayer Hall is a four story building that has offices on the first and second floor and has classrooms on the third and fourth floor. It is about 250m long and about 50m wide with the long sides of the building facing east and west. The exterior of the building is a granite block with very few exterior windows and no insulation on the exterior walls of the building. Because West Point is in the colder northeastern United States climate, the heat loss out of the exterior of the building can be significant. On all four floors, there are two hallways running length wise that allow either classrooms or offices on the perimeter with additional classrooms or offices on the interior as well. This causes significantly different heating zones in the interior and along the exterior of the building. Because the heating system is not perfectly tuned, some classrooms and offices in Thayer Hall have been very uncomfortable at times. The charts below in Figure 2 and Figure 3 show temperature readings for a classroom and an office during the winter months in Thayer Hall:

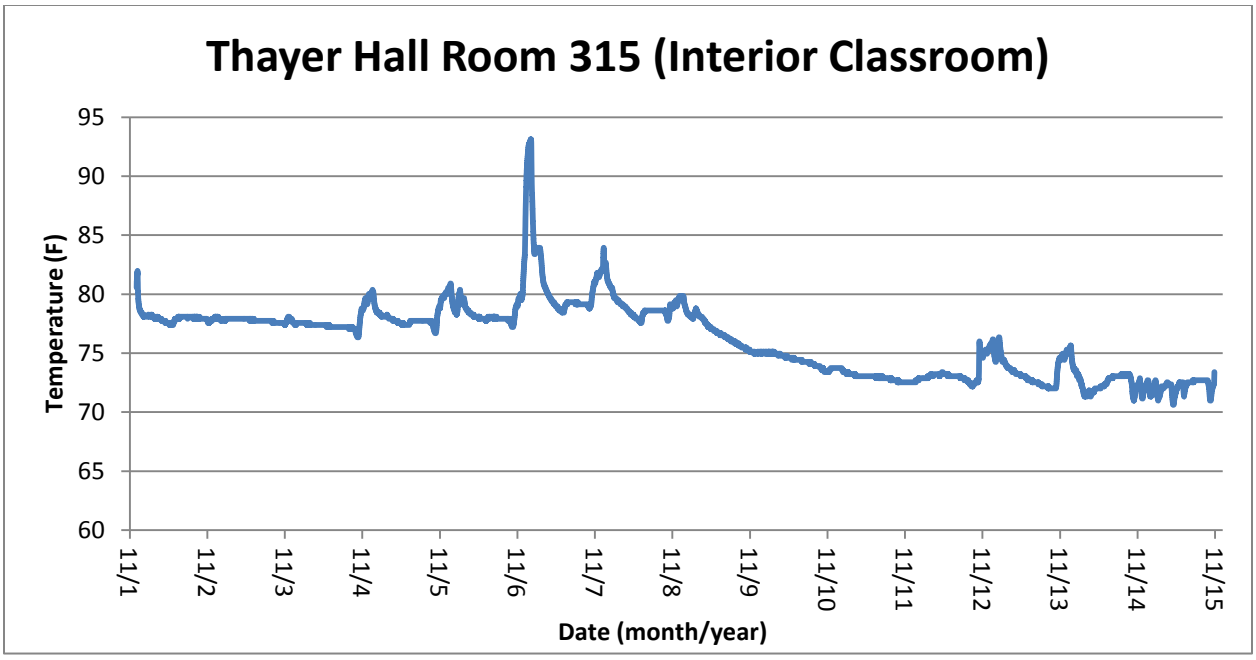

Figure 2: Thayer Hall Room 315

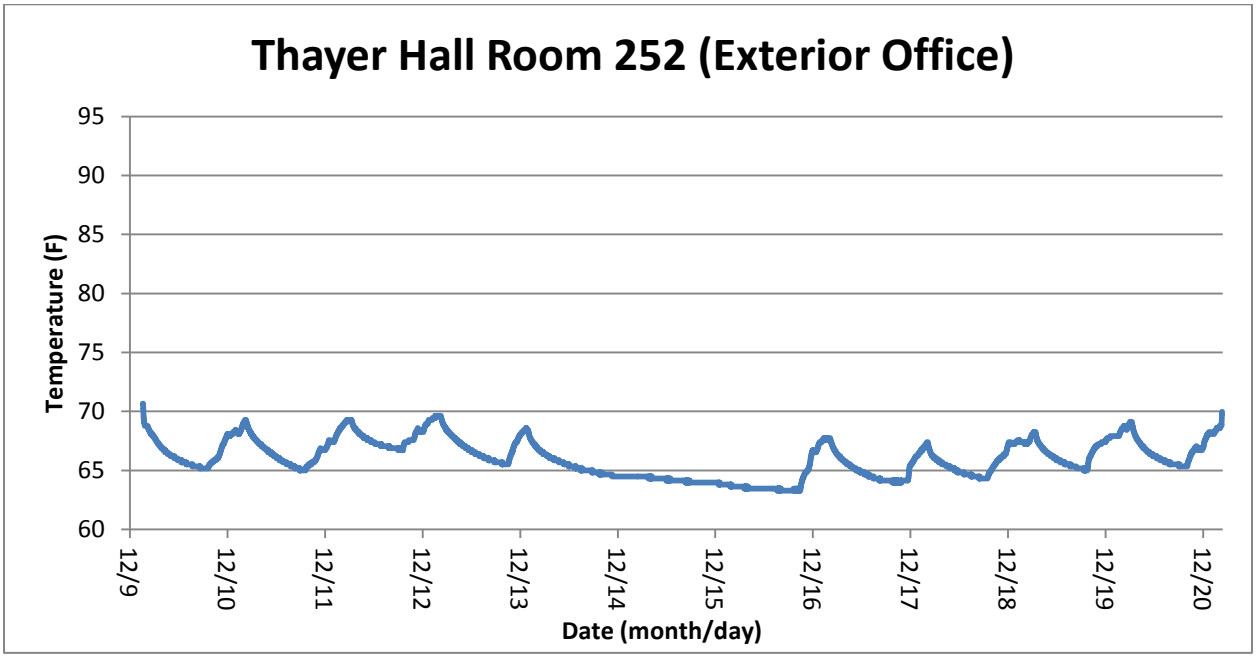

Figure 3: Thayer Hall Room 252

Figure 2 shows the data for room 315, an interior classroom, while Figure 3 shows the data for room 252, an exterior office. Both of these figures show that there is significant amount of time when these rooms are outside the normal thermal comfort zones.

The temperature was recorded for room 315 because many of the students in the classroom were complaining that the room was too hot. On the day that the classroom reached 93 degrees Fahrenheit, students were visibly distracted while sweat was streaming off each of their faces, and the teacher could visibly see that the students were having more trouble than usual paying attention. Because the outside temperature was the normal cool fall day in the northeast, these students' bodies had a difficult time dealing with this excessive heat in the classroom. When straw polled, 100% of the classroom felt uncomfortable and thought about their discomfort while in this classroom. According to Maslow, thinking about this discomfort would impede these students' ability to reach a higher level in the hierarchy, so the students are less likely to be as successful in learning the material taught at that time.

The temperature was recorded in room 252, because these office occupants and in many of the other occupants along the exterior wall of the building were feeling very cold in their offices. Teachers in the offices in this area of the building would often be seen putting on additional clothing to try to stay warm, and many instructors would only be able to work for an hour in their office before they would have to walk through the hallways to warm up. Occupants could be seen rubbing their hands together to try to warm up their hands as well. Both occupants in room 252 thought about their thermal discomfort at times while in their office, and all 20 occupants that had offices with the same situation thought about their thermal discomfort at times while in their office. Again, when occupants are thinking about being uncomfortable, they are not going to be as productive.

Mahan Hall is another historic building that has both offices and classrooms. It has four floors above ground with another six floors below the ground level and built into a hillside. The building is about 50m long and 25m wide, and the building's long sides are facing east and west. There are many more windows in this building than in Thayer Hall, but the building has the same exterior granite walls with no exterior wall insulation. Because this building is not as wide as Thayer Hall, all offices or classrooms are along an exterior wall, so there is not an issue with a large difference in interior versus exterior zones. But there is still an issue with thermal comfort in this building. The figures below show temperature readings for a classroom and an office during the winter months:

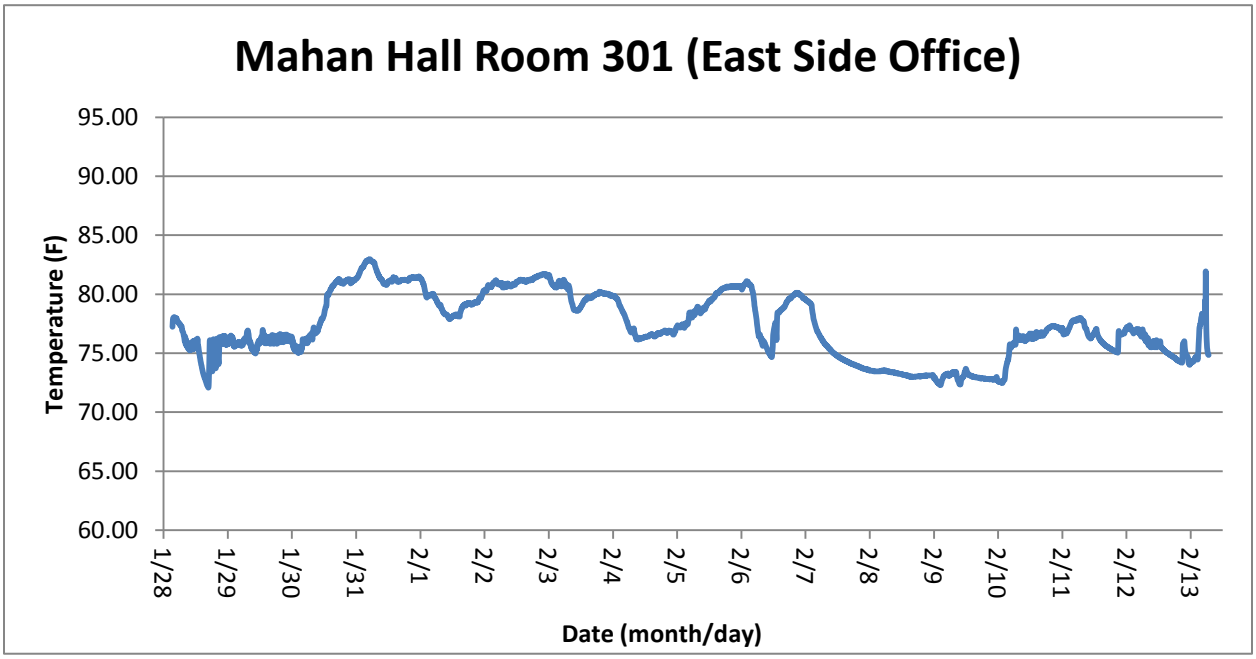

Figure 4: Mahan Hall Room 301

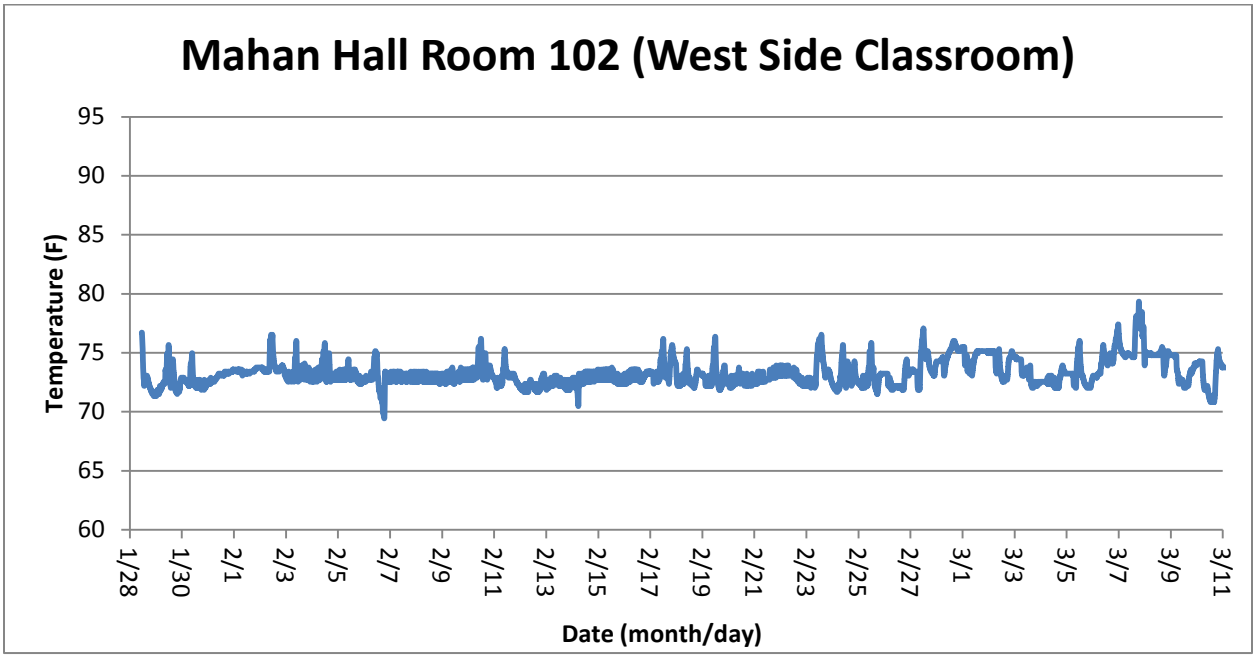

Figure 5: Mahan Hall Room 102

Figure 4 shows room 301, which is an office on the east side of the building with a lot of large windows, while Figure 5 shows room 102, which is a classroom on the first floor. The office on the third floor has a lot of the time outside of the comfort zone, but the classroom on the first floor is in the comfort zone much more often.

The temperature was recorded in room 301, because the occupant complained of the office being much too warm at times. This office has large windows overlooking the Hudson River to the east. Because of these large windows, there is a large amount of the sun's energy entering the room, which increases the temperature in the office. As shown in the chart above, there is a significant amount of time that the temperature is outside of the thermal comfort zone. This is contrary to popular belief that the sun's energy doesn't have huge impact on a large commercial building in a cold climate, but as you can see in Figure 4 above, there is additional heat in this room, making it uncomfortable for the occupant.

The temperature was recorded in room 102 because some students complained of being too warm at times. As shown in the Figure 5, this room doesn't have a lot of time outside of the thermal comfort zone, but the room's temperature often gets close. This room's excess heat at times is caused by an air infiltration issue. This room is on the first floor and is one of the rooms with the greatest distance to the front doors. The four metal front doors are not well maintained, so these doors don't completely close unless they are slowly pulled shut, which takes some time and effort. When students are going through these doors between classes, these doors are often left open at a 45 degree angle, which allows a lot of cold outside air to infiltrate into the interior of the building and causes the thermostat controls to increase the heat output to the first floor. Because room 102 is not near the door, most of the cold air does not reach this room, but the heat still pumps into this room. To measure the impact of the temperature on the students in this class, the students took a survey on days when instructed to do so. The students unknowingly took the anonymous straw poll only when the temperature in the classroom was between 75 and 76 degrees. Of the students that took the survey, 66% were comfortable in the classroom and 43% did not even think about the classroom temperature. But this means that a third of the class wasn't comfortable when the teacher was trying to teach them in the classroom, and more than half of the students thought about the temperature in the room before the survey. The true impact of this discomfort is difficult to actually assess, so the students were also asked if the temperature in the classroom made it more difficult to pay attention. Of the students in this

classroom, 34% of the students felt that the temperature in the classroom impacted their ability to learn when the temperature was only slightly outside the recommended comfort zone. This is a significant number of students, so improving the thermal comfort in a classroom could greatly increase the ability of students to pay attention and learn more information.

Techniques to Improve Thermal Comfort

Teachers have various ways to impact the thermal comfort in a classroom. In order to be successful at implementing these methods, teachers must constantly seek and analyze feedback from their students. Although these steps do not address all of the concerns related to thermal comfort, they do in fact provide a reasonable first step to combat the issue.

1. *Recognize when the students in a classroom are uncomfortable because of the room's temperature.* Although this seems like an obvious task a teacher should be tracking, more often than not, teachers are so focused in their preparation and execution of class that they often forget the basics. The simple tasks of changing classrooms upon recognition that there is a thermal comfort issues may be possible and could greatly increase the comfort level of the students.
2. *Seek and analyze student feedback.* In offices and classrooms where thermal discomfort was clearly identified, surveys and interviews were conducted in order to gather feedback on the impacts of the discomfort. Even if temperature and humidity readings indicate then thermal comfort is possible, it is imperative that the teacher solicit feedback from their students. Even when rooms were outside of the recommended readings for temperature and humidity, students did not always indicate that thermal discomfort was an issue.
3. *Implement low-cost and low-effort solutions*. Once thermal discomfort is clearly identified, instructors should try and implement low-cost and low-effort solutions. For example, if it is a hot summer day and thermal discomfort is an issue, students should be allowed to remove any unnecessary clothing, up to an appropriate level, as well as open windows and use fans to assist with air circulation. If it is really cold, students should be permitted to wear jackets and do everything possible to achieve a level of comfort. Although these trivial tasks may do little if anything to address the larger issue, psychologically it should improve the morale of the students and improve the students' perception of the teacher.

4. *Report the deficiencies to higher*. It is critical that teachers report any temperature and humidity problems to the management staff in the building. Do not assume that someone in the building already knows about the problem, and make sure to follow-up with your initial report.
5. *Recommend larger studies and data collection.* If similar problems continue to persist throughout the building, utilize comment cards or open-door policies to suggest a large-scale study and data collection to identify the problems in the building.
6. *Seek the most up-to-date building inspections and reports.* As mentioned earlier in this project, the most dangerous aspect of poor thermal comfort is bacteria and/or mold. It is critical for teachers to follow-up on any thermal comfort concerns they may have because may in fact be saving someone's life. Stay vigilant and continue to seek the truth. The more teachers are aware of the issues, the better their students will ultimately perform.

Conclusion

Teachers should be aware of the thermal comfort level of their classroom, because a classroom that is not comfortable will cause an unwanted distraction for the students, which has been shown through research in the area of Maslow's Hierarchy of Needs and through survey data. Maslow's Hierarchy of Needs shows that the basic needs of students need to be met before they can truly focus on the higher level of learning in the classroom. The survey data from the offices and classrooms at the United States Military Academy at West Point in Mahan Hall and Thayer Hall shows that most students feel distracted when the temperature is well out of the comfort zone. Even when the temperature is barely outside of the comfort zone, a significant portion of the classroom feels uncomfortable, and they believe that this discomfort is affecting their ability to learn. Because of the impact that thermal comfort can have on the classroom, the teachers should try to ensure the classroom is inside of the recommended thermal comfort zone by changing classrooms, implementing low cost and low effort solutions, and report the problem to get the problem fixed as soon as possible.

Works Cited

1. **Simons, Janet A., Irwin, Donald B. and Drinnen, Beverly A.** Maslow's Hierarchy of Needs. *Psychology- The Search for Understanding.* New York : West Publishing Company, 1987.

2. *A review into thermal comfort in buildings.* **Taleghani, Mohammad, et al.** 26, s.l. : Renewable and Sustainable Energy Reviews, 2013, Renewable and Sustainable Energy Reviews, pp. 201-215. 201-205.

3. **Nicol, J F.** *Thermal comfort: A handbook for field studies toward an adaptive model.* London : University of East London, 1993.

4. *Do Scholl Facilities Affect Academic Outcomes?* **Schneider, Mark.** 2002, National Clearinghouse for Educational Facilities, pp. 2-25.

5. **Onset.** Onset HOBO Data Loggers. [Online] Onset Computer Corporation, 1995-2015. [Cited: April 15, 2015.] http://www.onsetcomp.com/files/Onset-Environmental-Research.pdf.

6. *Web application for thermal comfort visualization and calculation according to ASHRAE Standard 55.* **Schiavon, Stefano, Hoyt, Tyler and Piccioli, Alberto.** 2013, eScholarship University of California, pp. 1-23.

7. *Thermal comfort field study in undergraduate laboratories- An analysis of occupant perceptions.* **Mishra, Asit Kumar and Ramgopal, Maddali.** 76, 2014, Building and Environment, pp. 62-72.

8. *Field studies on human thermal comfort- An overview.* **Mishra, Asit Kumar and Ramgopal, Maddali.** 64, 2013, Building and Environment, pp. 94-106.