

Exploring Classroom Temperatures: An Analysis of Student Preferences and Energy Usage



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Abstract

Boston College spends a large portion of their energy bill on the heating of classrooms. However, many students do not feel comfortable while learning in Boston College buildings. Our research aims to determine the student preferences, the reason behind those preferences, and to explain how Boston College can better regulate the temperature in their classrooms. By analyzing survey data and temperature data recorded in Stokes Hall, Gasson Hall, and Fulton Hall, we have determined that older buildings like Gasson Hall are more prone to temperature fluctuations, leading to students being uncomfortable. On the other hand, newer buildings like Stokes Hall are better equipped to provide comfortable temperatures to students, leading to better performance and less distractions.

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1 Introduction

Over 32% of Boston College's energy bill is spent on natural gas and oil, which is used to heat classrooms and dormitories throughout campus. In a previous study done in 2018, which evaluated the Boston College work order system, it was determined that while students were, in fact, dissatisfied with the room temperatures in the buildings at Boston College "it was not personally bad enough to warrant a work order" (Kang et al., 2018). However, it has been three years since this study was conducted and a common problem that is still often voiced by students at BC is that classrooms are either too cold or too warm. Hence, our research aims to evaluate Boston College's energy usage in classrooms in Fulton Hall, Gasson Hall, and Stokes Hall (North and South) by determining if there is a significant over-heating or over-cooling problem in Boston College classrooms. Furthermore, rather than focusing on modifying the work order system, our main goal is to determine whether or not the HVAC system used at BC needs to be changed and/or modified to support both the preferences of students at Boston College as well as improve the energy usage in classrooms. To further assess this problem our study focused mainly on the following four research questions:

1. What is the relationship between changes in the outside temperature and the temperature, taken from our device, in Boston College buildings? Is there variability across buildings?
2. What are students' preferences on the room temperature? Are they being over/under heated?
3. Does gender influence student comfort levels?
4. How does temperature affect performance in class/on exams?

1.1 Literature Review

Through an extensive research process, our group assessed various sources that helped mold the criteria and methods used in determining the student preferences and energy usage in buildings across the Boston College campus. Various studies have been conducted in regards to energy performances and classroom environments, such as a study titled Evaluation of School Building Energy Performance and Classroom Indoor Environment. Particularly, this study was useful in helping us decide on which of the BC buildings we wanted to focus our project on. One of the main aspects of this study was to compare the current state versus the renovation state of a set of classroom buildings located in the Central Europe region. As such, the results of the study showed that the school buildings were highly inefficient, even

if they were previously renovated because “indoor climate in classrooms is largely influenced by windows” (Mohelnikova et al., 2020). Consequently, our team began to question whether there was any significant relationship between the temperatures of previously renovated and/or newer buildings at Boston College. Hence, the buildings at BC proved to be the perfect subject for our research as the campus provides both newer buildings like Stokes Hall, which was built in 2011, and older buildings that have been previously renovated like Fulton Hall and Gasson Hall.

According to the U.S Department of Energy’s Buildings Energy Data Book, one of the main sources of energy consumption in buildings are from the use of Heating, Ventilation and Air Conditioning (HVAC) systems that utilize around 43% of the total energy consumption in buildings in the U.S. (“Residential Sector Energy Consumption,” 2012). As such, there has been previous research that focused on HVAC systems in office buildings. In this specific study, one of the main aspects that were identified was that “the diversity in occupants’ thermal comfort preferences is usually overlooked in the operations of centralized-HVAC buildings and room temperatures are maintained within a narrow temperature range” (Aryal & Becerik-Gerber, 2018). Hence, this study sought to understand the differences between personal comfort levels and the temperatures that office buildings were being set to. Once the differences were determined, the researchers discovered that if the buildings were changed to be set at the occupants’ personal comfort levels as opposed to the building level set point, there were energy savings up to 6.5%. Additionally, occupant preferences led to an average satisfaction of 63%, compared to average satisfaction of about 38% for the control case using the building level setpoint (Aryal & Becerik-Gerber, 2018). As such, the results of their study found that adhering to the personal preference of its occupants is considered a key factor in improving energy consumption.

Furthermore, while researching the relationship between personal preferences and temperature, there were also various case studies that included other social factors in correlation with personal temperature preference. For example, the topic of gender in relation to temperature preference seemed to be a popular area of study. One of the studies that peaked our interest was titled, The influence of acclimatization, age and gender-related differences on thermal perception in university buildings: Case studies in Scotland and England. This study used numerous methods including questionnaire surveys and high tech indoor environment measurement tools like Black-bulb thermometers, Anemometers, Relative humidity probes, and TRH USB loggers to determine whether gender and age had any influence on thermal perception (Jowkar et al., 2020). As such, the results of the study proved that although age didn’t really affect person’s temperature preference, the study did prove that thermal perceptions of females differed from men in a way that females seemed to feel colder

than males in university classrooms and thus, women generally displayed cooler sensations and warmer preferences as opposed to men in university classrooms (Jowkar et al., 2020). In particular, the methods used in this study was a major influence concerning our decision to use student questionnaires and thermostats in our study.

Additionally, the correlation between personal preferences and performance was also an aspect that we decided to research more on. Although our project did not specifically focus on this area of study, which would have required us to gain IRB approval, it was important to gain some insight on how temperatures in a building could affect a person's performance in an environment. For example, an excellent study conducted in Denmark titled, *The Effects of Moderately Raised Classroom Temperatures and Classroom Ventilation Rate on the Performance of Schoolwork by Children*, showed that reducing air temperatures in classrooms from 77°F to 68°F increased test scores in language and numerical based tasks as well as proved that students performed better when airflow through the classroom was increased (Haverinen-Shaughnessy & Shaughnessy, 2015). Furthermore, another study we also looked at also analyzed the effects of ventilation and temperature on student performance. Particularly, the main discovery of this study was that higher temperatures aren't ideal for students in a learning environment and that increased ventilation rates and decreased indoor temperatures led to better testing scores (Haverinen-Shaughnessy & Shaughnessy, 2015). The information provided from these two studies proved helpful in interpreting our data since, while our survey did not in any way ask any details on a student's performance in class, there were comments from students which voiced that high temperatures made them feel uncomfortable and thus, affected their performance in class by making them "sleepy" and/or "distracted."

2 Methods

In order to study the perception and impact of temperature on students in classrooms across Boston College's campus, we needed to know which classrooms are in use and which classrooms are used the most often. We began by reaching out to Boston College Student Services in order to determine which classrooms in Fulton, Gasson, and Stokes (North and South) were used most often throughout the week for in person classes. We were connected with Adam Krueckeberg from Student Services and we were lucky enough to have him work with us throughout the entire semester. Adam provided with us a list of all of the classrooms in Fulton, Gasson, and Stokes. The list included the number of students that each room could hold with reduced capacity for social distancing requirements, and the number of seat hours in each classroom. We analyzed this list and selected 21 classrooms. During the first week of analysis we focused on classrooms in Stokes. The second week we studied classrooms in Gasson and during the final week we focused on Fulton.

2.1 Collecting Data

We selected the classrooms based on several factors. First, all of the classrooms we selected had a high number of seat hours which means that they are being used for many hours each week. Because of this, we were hoping to get hundreds of responses to our survey. Second, we selected classrooms in a variety of locations within the academic buildings. We chose more classrooms in Gasson compared to Fulton and Stokes because we were informed by Bruce Dixon, the Sustainability and Energy Management Specialist for Boston College, that the HVAC systems in Gasson are not as consistent as in the other buildings. With the selected classrooms, we reached back out to Adam from Student Services who provided us with a complete list of every class and every professor who use the selected 21 rooms. From there, we collected the email addresses of every professor and wrote to them to let them know that we would be monitoring the temperature in their classroom during a specific week in the month of April. We sent the professors the following email:

For our research, we are installing thermometers in classrooms across Stokes, Fulton, and Gasson. During the week of April Xth we will be monitoring the temperature in your classroom and we would like your students' participation in our study. Attached is a powerpoint slide containing a QR code. We would appreciate it if you would incorporate this slide at the end of your lecture and ask the students to scan the code using their phones. Once they scan the code, they will be directed to a two minute quiz about the temperature and feeling in the

classroom at the time. It would be very helpful if the students could complete the quiz every day that they are in the classroom during this week.

The temperature was monitored in the selected classrooms for the entire week that the thermometers were installed. We also monitored the outside temperature but didn't change the questions on the survey depending if it was a particularly hot or cold day throughout our study.

2.2 Survey

In order to collect data from the students in the selected classrooms, we created a survey that was accessible through a QR code. The survey consisted of seven questions. The starred questions below were required to be answered.

1. What classroom are you in? (Building and Room Number)
2. How do you feel about the temperature in your classroom?
3. Are any of the windows open in your classroom?
4. Gender
5. Do you tend to always feel hot or cold? Or do you not notice?
6. In general, do you prefer to feel colder or warmer?
7. Any other thoughts about the heating or cooling of classrooms at BC?

We asked that the students scan the QR code and complete the survey at the end of class. Because we relied on professors to add the QR codes to their slide dock for their lecture, we can't be 100% certain that every survey participant completed the form at the end of class, however, by looking at the times we received responses, most of them were recorded at the typical end of a class period. We decided to use a QR code that was attached on a powerpoint slide as supposed to hanging a piece of paper with a QR code in the specific classrooms because we weren't able to receive permission from Student Services.

2.3 Materials

We used 10 Govee H5072 Hygrometers to gather temperature and humidity data for our study. The 10 thermometers allowed us to record the temperature in each individual room over the course of the week. At the end of each week, the hygrometers were collected from their rooms, and the data was synced. Then, they were moved to the next round of rooms to collect the next set of data.

3 Results

3.1 Outside vs Inside Temperatures and Building Variability

What is the relationship between changes in the outside temperature and the temperature, taken from our device, in Boston College buildings? Is there variability across buildings? We can analyze the relationship between inside and outside temperature by comparing our readings from thermometers inside Boston College buildings to historical temperature data provided by Weather Underground.

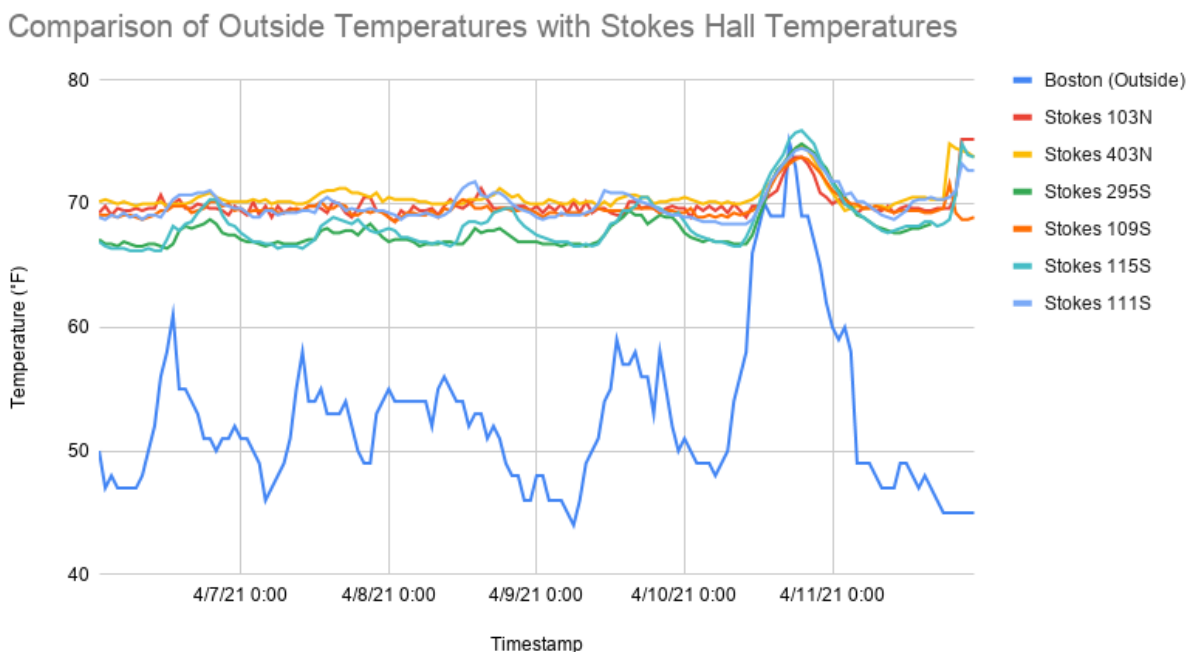


Figure 1: A graph displaying the temperature (in degrees fahrenheit) of selected rooms in Stokes Hall and the outside temperature.

Over the course of each individual day, outside temperatures cool in the early morning, then start to rise in the late morning, peak in the afternoon, and then settle again at night. On the other hand, as seen in Figure 1, the temperatures of the rooms are usually in the high 60°F or low 70°F range throughout the entire day. Excluding April 10th, the lowest temperature recorded outside was 44°F on April 9th at 6pm, while the highest outside temperature recorded was 61°F. During this same time period, the lowest temperature recorded inside was 66°F, while the highest temperature recorded inside was 72°F. These results show that the HVAC system in Stokes Hall is able to keep the temperatures consistent during cool weather. The data for April 10th shows how the Stokes Hall HVAC system is able to adapt

to quick increases in outside temperature. On this day, the outside temperature rose up to 75°F, the high for the week. What follows this spike in outside temperature is a spike in inside temperatures. All monitored rooms in Stokes Hall reached 74°F, with a high of 76°F.

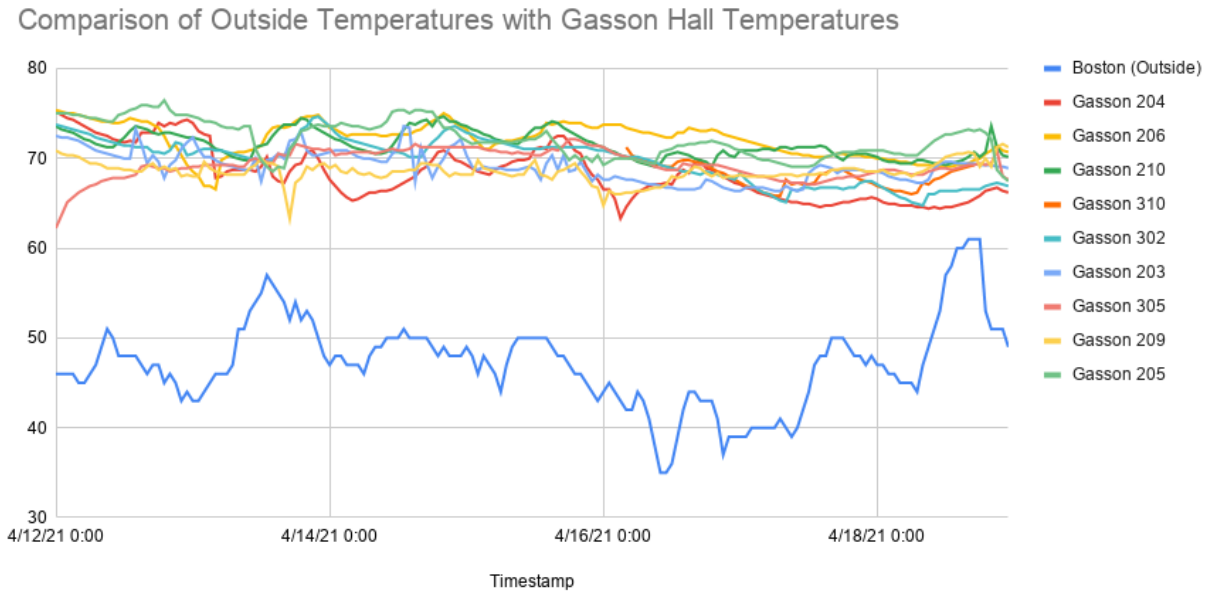


Figure 2: A graph displaying the temperature (in degrees fahrenheit) of selected rooms in Gasson Hall and the outside temperature.

Figure 2 shows the outside temperature in comparison to the inside temperatures for 10 selected rooms in Gasson Hall. During the observation period, the lowest temperature recorded outside was 35°F while the warmest was 61°F. Inside the buildings, the lowest temperature recorded was 66°F, while the highest temperature recorded was 76°F. When compared to Figure 1, the room temperatures in Gasson are much more variable. Instead of room temperatures being consistent from day to day (except for exceptionally warm days), temperatures vary greatly.

Comparison of Outside Temperatures with Fulton Hall Temperatures

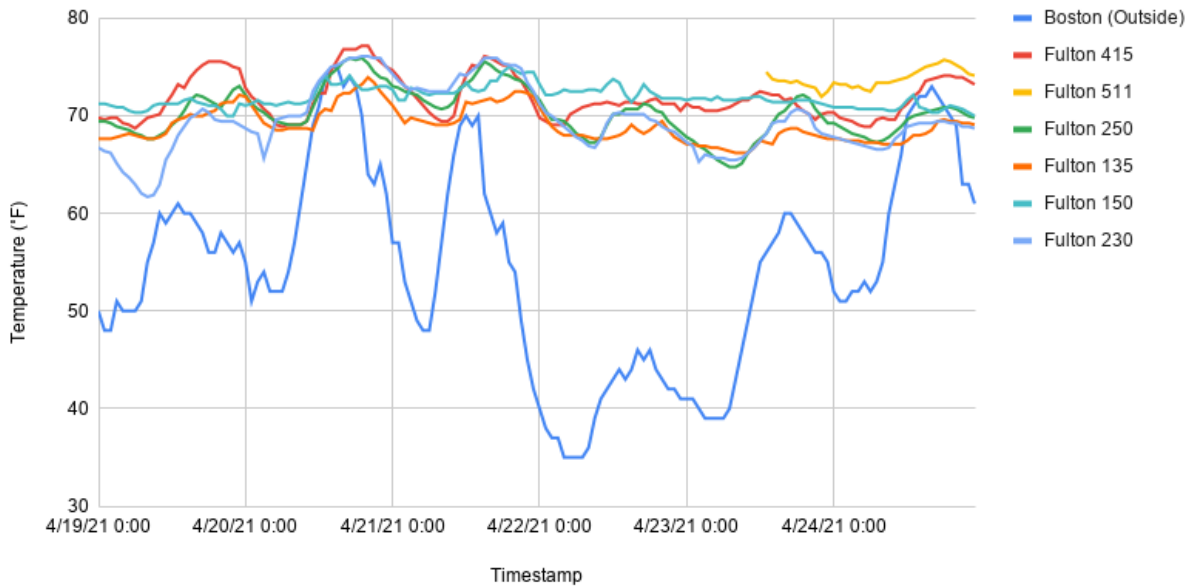


Figure 3: A graph displaying the temperature (in degrees fahrenheit) of selected rooms in Fulton Hall and the outside temperature.

Figure 3 shows the outside temperature in comparison to the inside temperatures for the 6 selected rooms in Fulton Hall. Our temperature data shows that the lowest temperature recorded outside was 35°F, while the highest temperature recorded outside was 75°F. Inside the classrooms, temperatures ranged from a low of 62°F to a high of 77°F. In general, the outside temperatures for the week that temperature data was being recorded in Fulton Hall were much more variable. On April 20th, and 21st, temperatures peaked in the afternoon, leading to exceedingly warm classroom temperatures. One common result found throughout all three buildings is that on days where the outside temperature is much hotter than normal, the HVAC systems in each building fail to prevent the inside temperatures from reaching 75°F or greater.

Distribution of Temperature Readings in Boston College Buildings

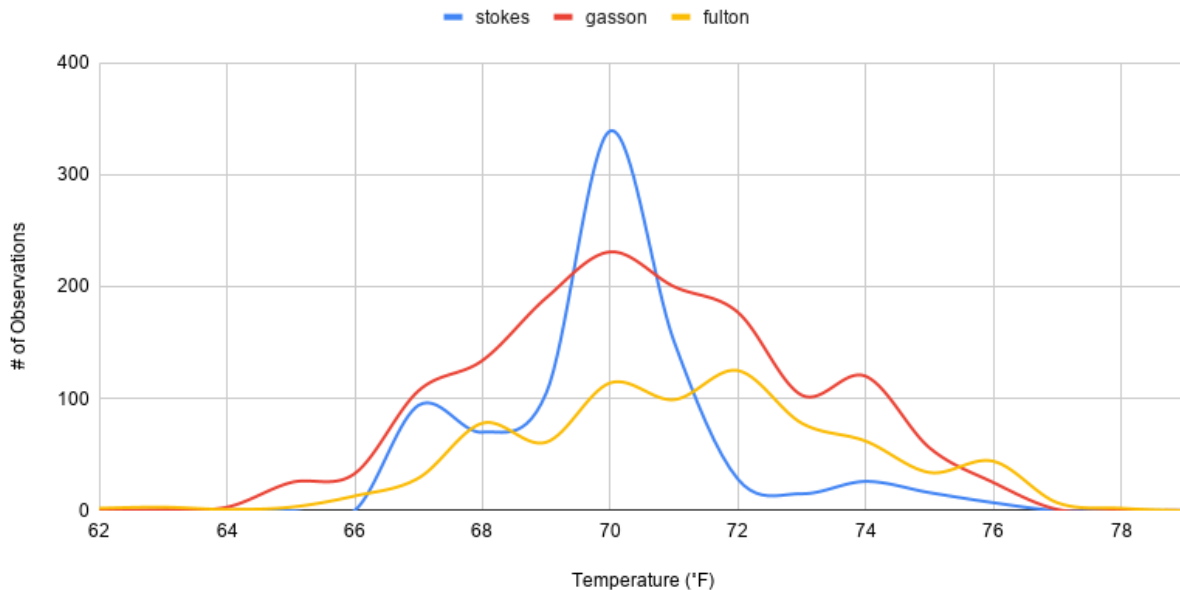


Figure 4: A graph displaying the distribution of temperature recordings in all three monitored buildings.

Figure 4 shows the distribution of temperatures recorded in each building. This graph shows that the temperatures recorded in Stokes Hall fall into a small range. The temperatures are almost always near 70°F. However, when it comes to the distribution of temperatures in Gasson Hall and Fulton Hall, it is much more spread out. In Stokes Hall, 73% of recorded temperatures in Stokes Hall were in the 68°F to 72°F range, while only 57% and 53% of temperatures were in that range for Gasson Hall and Fulton Hall, respectively.

3.2 Student Temperature Preferences

What are students' preferences on the room temperature? Are they being over/under heated? The pie charts above show the percentage of students who felt that their classroom in Stokes, Gasson, or Fulton were too hot, too cold or just right. In Figure 5, 73.6% of the students, or 106 students, said that their classroom felt like it was the right temperature. 14.6% of the students said the classroom was too cold and 11.3% of the students said the classroom was too hot. Overall, the temperature in the classrooms in Stokes were the most satisfactory to the students compared to Gasson and Fulton. Figure 6 shows that only 48.7% of the students, or 37 students, felt that their classroom in Gasson was a satisfactory temperature. 36.8% of the students felt that the classroom they were sitting in was far too hot. Figure 7

shows that 59.5% of students felt that their classroom temperature in Fulton was just right. Similarly to Gasson, more students felt that their classroom was too hot rather than too cold. The word cloud shown in Figure 8 comes from a collection of comments that students left on the survey. The most commonly seen words in the comments appear larger in the word cloud. It is clear that many of the students feel that the temperature in Gasson is inconsistent and generally too hot.

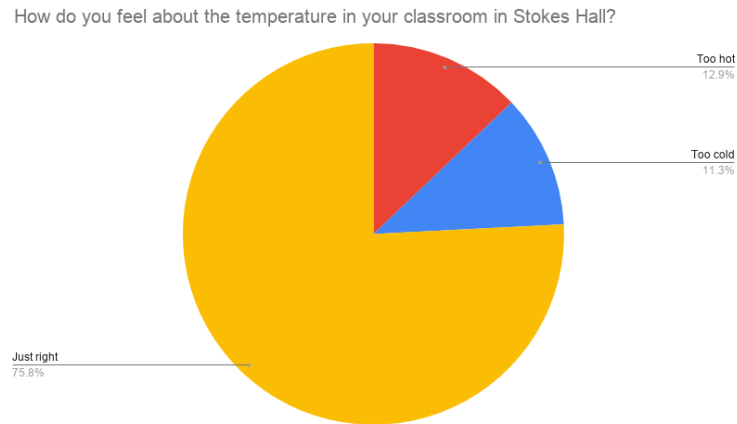


Figure 5: This figure shows the percentage of respondents that felt that their classroom in Stokes Hall was too hot, too cold, or just right.

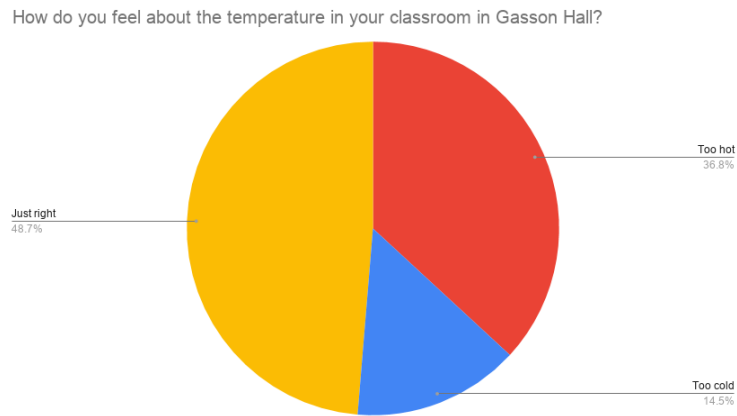


Figure 6: This figure shows the percentage of respondents that felt that their classroom in Gasson Hall was too hot, too cold, or just right.

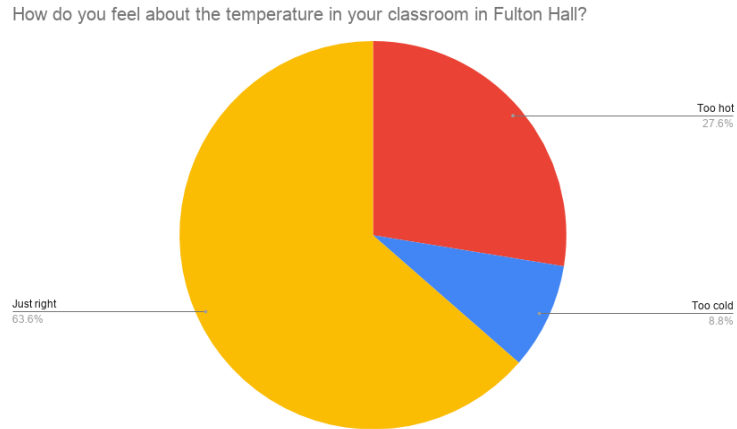


Figure 7: This figure shows the percentage of respondents that felt that their classroom in Fulton Hall was too hot, too cold, or just right.

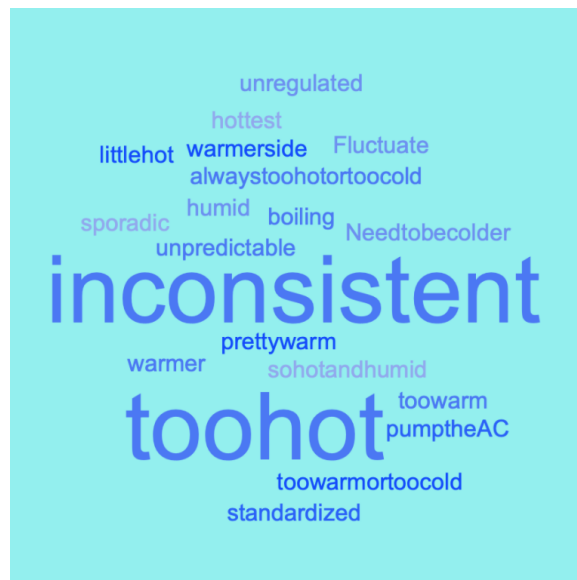


Figure 8: A word cloud of student temperature sentiments, made using comments left by participants.

3.3 Gender

Does gender influence student comfort levels? Another aspect of student comfort levels we aimed to explore was the effect of gender. We wanted to survey our respondents to determine their usual comfort level - did they feel they tended to run hot or cold on an average day? As shown in Figure 9 , those who tend to run cold are overwhelmingly female, while those who tend to run hot are mostly male. Additionally, those who didn't tend to run hot or cold were also mostly male. This shows that in colder temperatures, females are more likely to be uncomfortable, because they already tend to run cold. On the other hand, it shows that in higher temperatures, males are more likely to be uncomfortable, because they already tend to run hot. Figure 10 shows this exact phenomenon. Out of those survey responses that indicated they were too cold, most of them were women. Additionally, the survey responses that indicated that they were too hot were mostly men. These results align with the results of the Figure 9 and findings from previous studies.

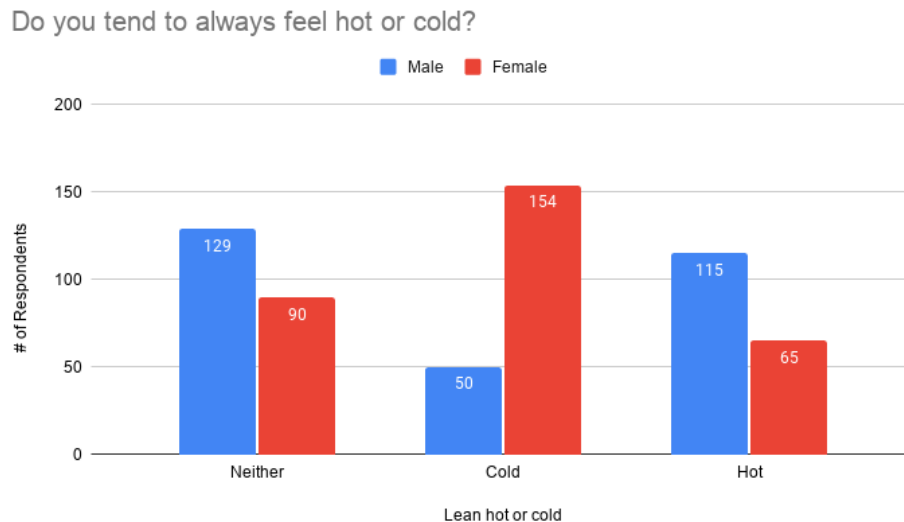


Figure 9: This figure shows the number of respondents and their gender to the question: Do you tend to always feel hot or cold?

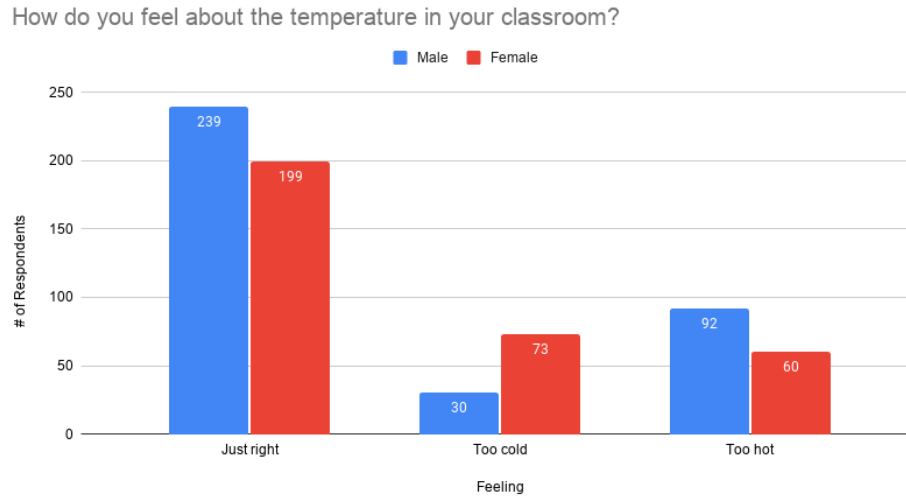


Figure 10: This figure shows the number of respondents and their gender to the question: How do you feel about the temperature in your classroom?

3.4 Student Performance

In alignment with information from our literature review about the impact of temperature on academic performance, we received some comments on the survey that are relevant. One professor wrote, “My students and I find the excess heat really distracting. Cold is less of a problem.” A student added, “I’ve been in some rooms that are so hot it makes me sleepy!!” Another student wrote simply, “I love when the windows are open and there is a nice breeze— literally nothing in the world worse than sitting in a hot classroom.” There were some students who mentioned that a cold classroom is equally unbearable. However, most of the comments, especially from those students taking class in Gasson, complained of the heat impacting their academic performance.

4 Discussion

From Figures 5, 6, and 7, it is clear that the classroom temperatures in Gasson are the least satisfactory to students. A majority of the students who responded to the survey felt that their classroom was either too hot or too cold. In Fulton, the majority of students did say that the temperature felt just right but a high percentage of the respondents still felt that the classroom was too hot. The classrooms in Gasson do not regulate the temperature in the same way that the classrooms in Stokes do. One student left a comment that demonstrated that they picked up on this difference, “The newer buildings are usually good. In the older buildings I am always hot.” Overall, the temperature of classrooms in Gasson and Fulton are incredibly inconsistent. Stokes, a new building, does not have the same problems with temperature regulations as shown in the Figure 4. Additionally, gender seems to play a huge role in overall perception of temperature. Because, more women than men said they tend to lean cold, more women than men also tended to say that their classroom was too cold. It is therefore important to note that the classroom cannot be concluded to be scientifically too cold or too hot since the perception of temperature is related, in some way, to gender. In regards to temperature and its relationship to academic performance, we cannot conclude anything with the results of our study. Although we received many comments from students who said they felt they were less productive in a hot environment, we did not measure their test scores. A study that could be done as a follow up to ours would be to measure the students’ test scores while recording the indoor temperature of the classrooms that they took the exam in.

4.1 Recommendations

One issue in the classroom buildings that we found to be fairly consistent was the fluctuation of the indoor temperatures in accordance with the fluctuations of the outdoor temperature. On days where the temperature spiked outdoors, it also rose indoors. This phenomenon can be seen in Figure 1 and Figure 2. Speaking to campus energy use, it would be helpful to ensure that the outdoor temperature is taken into account when determining what the temperature of the classrooms should be set to each day. Additionally, as the climate crisis continues to worsen, heat waves will become more prevalent. It is important that those warmer days are accounted for in the heating and cooling plans on Boston College’s campus. It would be unproductive to leave the heat blasting on a day when the temperature is close to 80 degrees Fahrenheit. Perhaps a central heating system that is difficult to change and update on a daily basis is not the best option as the prevalence of heat waves continues to increase in the future.

Furthermore, we would also like to recommend that the Boston College Facilities team adopt more transparency in terms of providing the student body with specific information regarding the thermostat policy and thermostat use in Boston College classrooms. For instance, unfortunately we were unable to get any information on the exact temperature range that BC sets their classrooms in Gasson, Fulton, and Stokes (North and South). Hence, we recommend that Boston College mirror the Thermostat Policy and Thermostat Use page on the Harvard Law School website which essentially provides a vast amount of information such as what the temperature of the buildings at Harvard Law are set at within seasonal ranges. For example, the website provides both the temperature set in colder weather (October-May) in which buildings are heated at 70° F as well as the temperature in the warmer weather (May-October) in which air conditioning is turned on and rooms are cooled 74°F (“Temperature Policy & Thermostat Use,” n.d.).

5 Acknowledgements

We would like to thank Adam Krueckeberg from BC Student Services first and foremost for helping us with this research project. Without his responsiveness, we would not have been able to gather the necessary material each week in order to contact every professor and select our classrooms. We would also like to thank every Boston College professor who added our QR code to their lecture slide dock and every Boston College student who scanned the code and completed the survey. Finally, we would like to thank both Tara Pisani Gareau for her guidance and wisdom throughout the semester as well as the Environmental Studies Department for providing us with the 10 Govee H5072 Hygrometers.

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