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Article:	**Thermal Comfort Prioritization in Public Building Design: Evaluation of Government College of Technology, Narowal as a Case for Enduser Satisfaction in Selected Environmental Parameters.**
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ABSTRACT

Thermal comfort is considered as one of the most critical environmental variable to the health and better performance of the students in an academic setting. Its poor performance may lead to poor performance of the students and teachers. Due to extreme weather conditions in recent climate patterns, Narowal city academic institutions need to explored in this perspective. Narowal Govermnet technology was taken as case study since it has many shifts during the whole day across the year and building was newly build. Review of literature identified major variables and methodology to be followed. Research concluded that winter was better perceived by end users as compared to summer. One of the basic reason was the planning of the overall building in one unit while multiple blocks could have been developed. With much longer and comparatively severe summers, spaces with less occupancy could have been on the South, West and South – Western sides. Better utilized and preferred spaces were mainly East, North and North- Eastern spaces. It was also concluded that adding higher ceiling height but not enhancing cross ventilation or air velocity had negative impact on the end user satisfaction and usage of the space. Apart from orientation, lack of insulation in walls and roof also created some of the major issues related to thermal comfort by adding and raising the internal temperatures in the explored spaces and creating occupancy issues. In summers, 66% were highly unsatisfied while 21% were unsatisfied with the temperature they were feeling along with 88% wanted it to be cooler. Design interventions as recommendations were proposed to over these issues.

Keywords: Thermal comfort, Natural lighting, Temperature, Humidity, Narowal city, Climate responsive design.

1. Introduction

Individuals spend most of their time indoors in modern societies. It has become increasingly important in recent years since thermal comfort has been linked to productivity and wellbeing and the conservation of energy in schools (Katafygiotou & Serghides, 2014). Education lies at the heart of any society and hence ensuring better indoor quality will enhance quality of education too (Dang & Chen, 2018). Colleges are mainly liable to elevated temperatures because of the young age of occupants, high occupancy densities, and confined opportunities for behavioral modifications to improve thermal consolation in lecture rooms (Mishra, Derks, Kooi, Loomans, & Kort, 2017). Students performance is related with environmental condition of the spaces in which they study. Colleges are an integral component to technical and engineering education in Pakistan. Lack of comfortable environment in these spaces and rooms create hurdles for the students to enhance their learning and perform to their best (Hamzah, Gou, Mulyadi, & Amin, 2018). . In the current timeframe of global warming, climate change and allied environmental issues, addressing these factors is critical to better designing of learning environments (Singh, Ooka, & Rijal, 2018). In academics and other activities, the thermal atmosphere of a classroom affects the improvements and outcomes of the students. Students must be provided with a comfortable learning environment to improve their productivity and speed of learning (Corgnati, Filippi, & Viazzo, 2007). Hence the research aimed to address the issue of thermal comfort evaluation, sensitization and performance in selected academic settings. In order to take forward the research, following research objectives were set forth:

1. To assess the thermal comfort parameters in MKGCT College by measuring temperature.
2. To evaluate the user perception in terms of acceptability and preference of extreme temperature conditions in selected building through respondents data.
3. To analyze the thermal comfort of users with building design.

This study created awareness about the importance of thermal comfort and its impact on the performance of students in the context explored. The research was also helpful in the building of the classroom for next expansion in the college facility. The research opened doors for the similar context evaluation. It also added interventions based on the current study to improve the current conditions. The research has a significant role to play as it defines the current issues of the modern day timeline with focus on the local climatic implication with respect to energy crisis as it can be addressed through future environmental design interventions for the existing as well as to be built academic institutions in future.

Review of Literature

Some of the elements which have an effect on thermal comfort have a major influence on occupants' satisfaction level. And these mainly include air temperature, humidity, radiant and air movement (Simion, Socaciu, & Unguresan, 2016). Furthermore, there is the metabolic rate produced by human activity and clothing isolation of the body as shown below in figure 01.

Figure 01 Thermal comfort variables (Simion, 2015)

The average student invests about a third of his time in school for instructional and training purposes. Extremes in indoor classroom temperatures have been shown in studies to have a significant impact on students' academic abilities. It's difficult to focus on class work and assignments while this happens (Gou, Lau, & Chen, 2012). According to recent research, there is a positive relationship between student performance and thermal comfort (Rodriguez, Coronado, & Medina, 2019). Temperature, humidity, air speed, and carbon dioxide are all variables that affect natural air or atmospheric conditions (Wang, Li, Ren, & He, 2014). . According to the NEU, the minimum temperature in classrooms should be 18°C. The value of thermal comfort is starting to be recognized by policymakers. "Schools or colleges are more than buildings; they are cultural centers, where children develop skills and find safe havens for the remainder of their lives," said Damian Hinds, the Education Secretary at the time. As a result, it's important that they're in the finest possible form. "The idea of thermal comfort is slowly making its way into educational policy" (Nico, Liuzzi, & Stefanizzi, 2015).

Narowal is a major city in the province of Punjab, Pakistan has a long summer season with temperature range between 19-42^{o} Centigrade while lower range of 7-29^{o} Centigrade in Summer and winter season respectively. extreme high temperatures lies in April-August months. Air pressure and wind speeds are negatively correlated with higher speed values in the summer season which may help in enhancing the cross ventilation if incorporated in the building design. High humidity is observed in rainy season between January-March and JuneAugust due to monsoon rains. High rainfall days also fall into the June-September months followed by cloud cover respectively. Average daily sun shine hours and day hours are ample to support the educational activities across the year.   The major variables under consideration were air temperature, air velocity or in local context cross ventilation, radiant temperature and relative humidity along with additional variables activity level and clothing. These variables if not controlled as per the weather conditions, building orientation, exposure to sun, building design and materials selection, relative closeness to the openings and direct exposure to climatic conditions may lead to uncomfortable environment and conditions and hence would negatively impact the students working capability to learn, focus and stay attentive in the classroom for lecture sessions.

Research Methodology

The overall research methodology followed is shown below in figure 2.

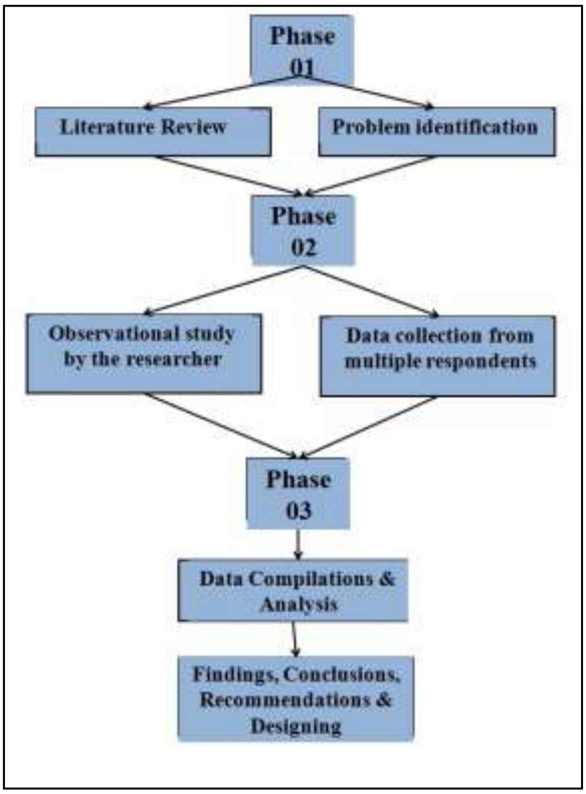

Figure 02 Research phases and major steps

In order to carry forward the research, an observational sheet was developed and used in both summer and winter season to complete observational study based on the variables explored i.e. Orientation, Space size, Space usage, Floor level, Temperature, Humidity, Cross ventilation and overall ambient feeling. A questionnaire was also used to collect data from respondents in both seasons and then was compared with each other. Sample size kept in both seasons was 100 and it also included 20 teachers. Teachers in both seasons were almost the same however, students engaged as respondents were half from the summer whose data was again collected in winter season.

Data Collection & Analysis

Taking the research forward, Mehmood Khan Government College of Technology (MKGCT) Narowal was documented and physically visited multiple times to evaluate and collect data as well as completing the observational study. College documentation and site figures are shown below:

The building floor plans of the selected building are shown below in Figures 4.1 & 4.2.

Figure 03 Ground Floor Plan of the Government College of Technology

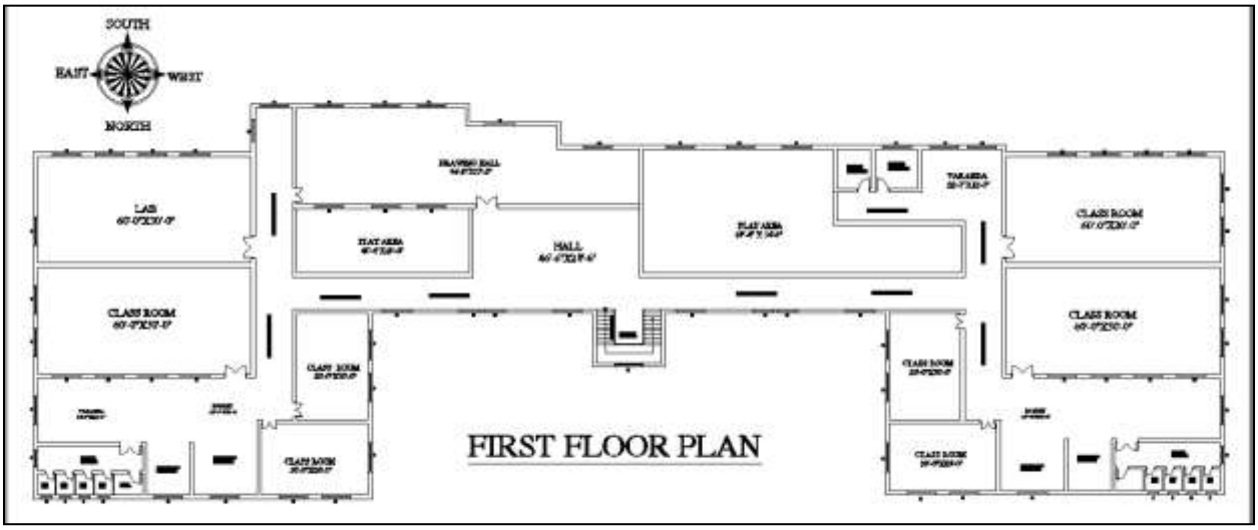

Figure 04 First Floor Plan of the Government College of Technology

As shown above in figure 3&4, architectural plans of the buildings are shown. They have an axis on East-West side while North-South are the major facing sides of the building. Blow up plans with highlighted areas of data collection and observational study are marked below.

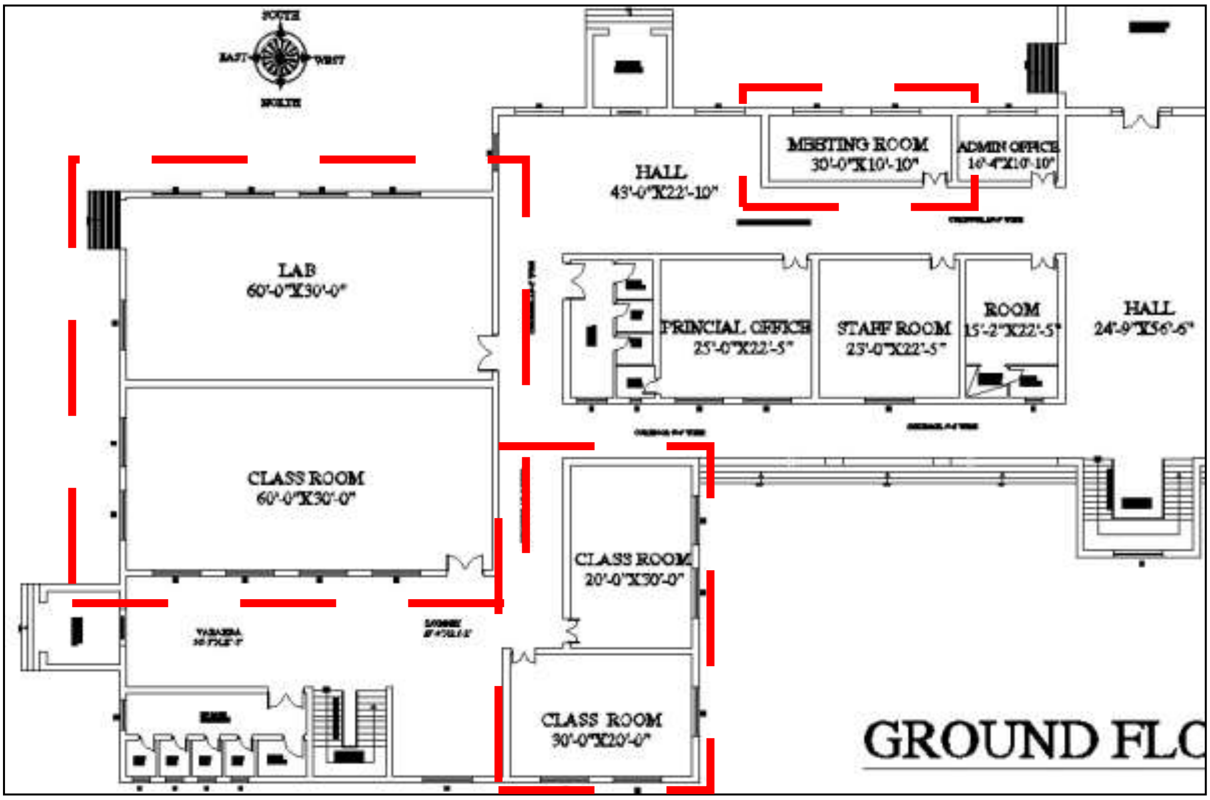

Figure 05 Ground Floor East Wing Plan of the Government College of Technology

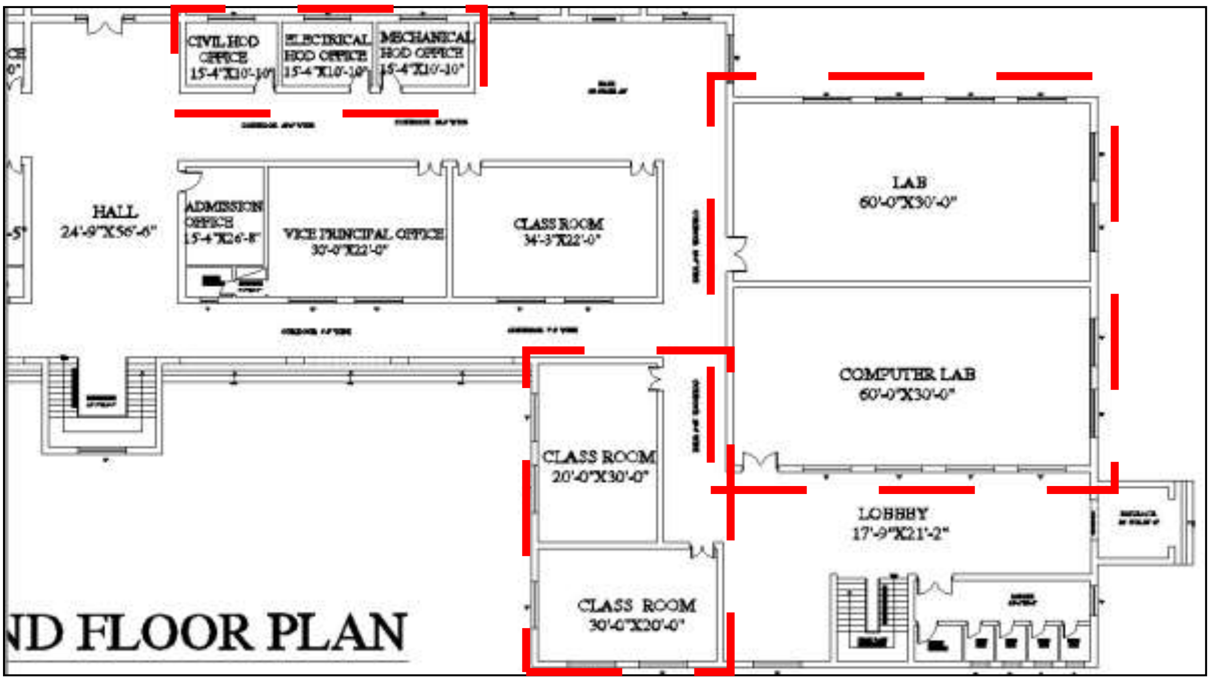

Figure 06 Ground Floor West Wing Plan of the Government College of Technology

As shown above in figure 5&6, Ground floor blow up plans are highlighted with major spaces under exploration with respect to both observational study and respondents data collection. On East side it mainly included three classrooms with multiple sizes and orientation, one large lab and one meeting room. On West side it included multiple classrooms, two labs with one computer lab and three HoD's offices.

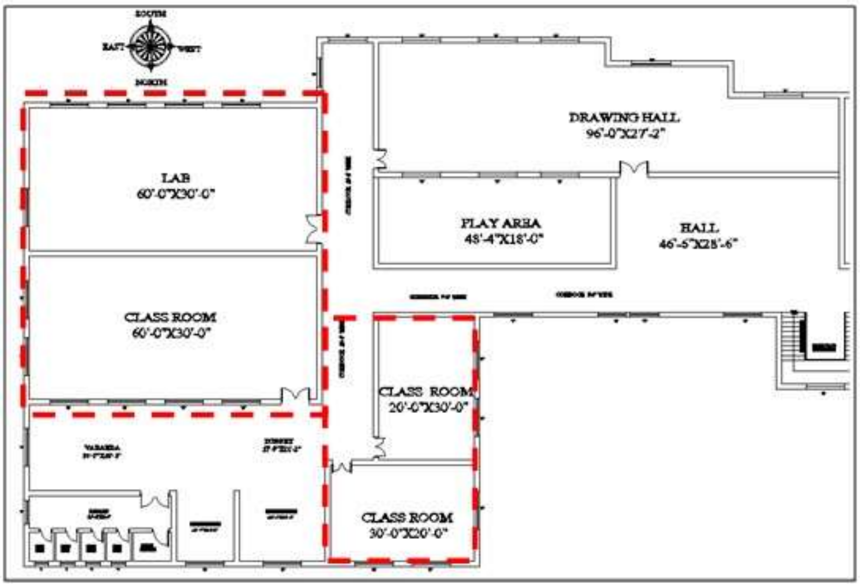

Figure 07 First Floor West Wing Plan of the Government College of Technology

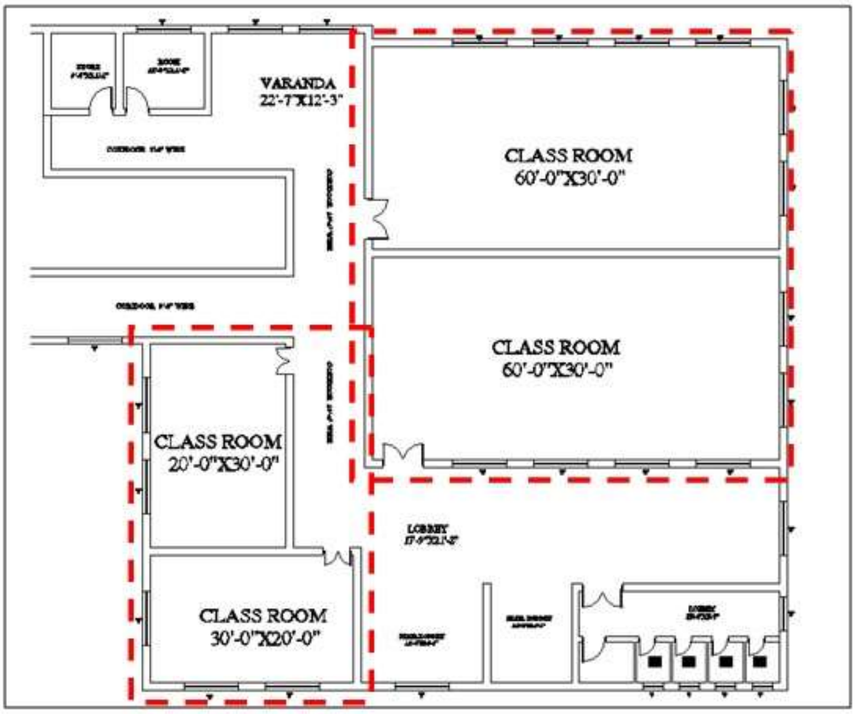

Figure 08 First Floor East Wing Plan of the Government College of Technology

As shown above in figure 7&8, First floor blow up plans are highlighted with major spaces under exploration with respect to both observational study and respondents data collection. On East side it mainly included three classrooms with multiple sizes and one large lab. On the West side, it mainly included four classrooms with different sizes and orientations. As shown above in the figures, selected Government College of Technology mainly consists of two floors with East West orientation. Each floor has diverse functions and have been extensively used by students and faculty as per designated functions. Selected areas for data collection have been highlighted with dotted rectangles over the spaces.


Figure 09 Perspective of MKGCT & North Perspective



Figure 10 Interview view of the classroom, ventilators and openings

As per shown above in the figure 9&10, internal and external views of the project site were explored. The observational sheet data completed for both seasons is shared below:

Table 01 - Summer Observational Sheet

S.No	**Floor**	**Orientation**	**Space Name**	**Size**	**Temperature**	**Humidity**	**Cross Ventilation**	**Overall Feeling**
1	Ground	South East	Lab	60 x 30	32	Moderate	Moderate	Moderate
2	Ground	East	Classroom	60 x 30	30	High	Poor	Uncomfortable
3	Ground	North	Classroom	30 x 20	30	High	Poor	Moderate
4	Ground	North West	Classroom	30 x 20	32	Moderate	Moderate	Moderate
5	Ground	South	Meeting Room	30 x 11	34	High	Poor	Uncomfortable
6	Ground	South	HOD Civil	15 x 10	34	High	Poor	Uncomfortable
7	Ground	South	HoD Elec	15 x 10	34	High	Poor	Uncomfortable
8	Ground	South	HoD Mech	15 x 10	34	High	Poor	Uncomfortable
9	Ground	South West	Classroom	60 x 30	33	Moderate	Moderate	Moderate

10	Ground	West	Classroom	60 x 30	34	High	Poor	Uncomfortable
11	Ground	North East	Classroom	30 x 20	30	Moderate	Moderate	Moderate
12	Ground	East	Classroom	30 x 20	30	High	Poor	Moderate
13	First	South East	Lab	60 x 30	32	Moderate	Moderate	Moderate
14	First	East	Classroom	60 x 30	30	High	Poor	Moderate
15	First	North	Classroom	30 x 20	30	High	Poor	Moderate
16	First	North West	Classroom	30 x 20	32	Moderate	Moderate	Moderate
17	First	South West	Classroom	60 x 30	34	Moderate	Moderate	Uncomfortable
18	First	West	Classroom	60 x 30	34	High	Poor	Uncomfortable
19	First	North East	Classroom	30 x 20	32	Moderate	Moderate	Moderate
20	First	East	Classroom	30 x 20	30	High	Poor	Moderate

Table 02 - Winter Observational Sheet

S.No	**Floor**	**Orientation**	**Space Name**	**Size**	**Temperature**	**Humidity**	**Cross Ventilation**	**Overall Feeling**
1	Ground	South East	Lab	60 x 30	22	Moderate	Closed	Moderate
2	Ground	East	Classroom	60 x 30	19	Moderate	Closed	Uncomfortable
3	Ground	North	Classroom	30 x 20	20	Moderate	Closed	Moderate
4	Ground	North West	Classroom	30 x 20	21	Moderate	Closed	Moderate
5	Ground	South	Meeting Room	30 x 11	22	Moderate	Closed	Uncomfortable
6	Ground	South	HOD Civil	15 x 10	22	Moderate	Closed	Uncomfortable
7	Ground	South	HoD Elec	15 x 10	22	Moderate	Closed	Uncomfortable
8	Ground	South	HoD Mech	15 x 10	22	Moderate	Closed	Uncomfortable

9	Ground	South West	Classroom	60 x 30	24	Moderate	Closed	Moderate
10	Ground	West	Classroom	60 x 30	23	Moderate	Closed	Uncomfortable
11	Ground	North East	Classroom	30 x 20	20	Moderate	Closed	Moderate
12	Ground	East	Classroom	30 x 20	20	Moderate	Closed	Moderate
13	First	South East	Lab	60 x 30	20	Moderate	Closed	Moderate
14	First	East	Classroom	60 x 30	19	Moderate	Closed	Moderate
15	First	North	Classroom	30 x 20	20	Moderate	Closed	Moderate
16	First	North West	Classroom	30 x 20	23	Moderate	Closed	Moderate
17	First	South West	Classroom	60 x 30	24	Moderate	Closed	Uncomfortable
18	First	West	Classroom	60 x 30	24	Moderate	Closed	Uncomfortable
19	First	North East	Classroom	30 x 20	22	Moderate	Closed	Moderate
20	First	East	Classroom	30 x 20	21	Moderate	Closed	Moderate

As shown in the above table 01 & 02, Overall winters was much more better as compared to summers, since students were wearing jackets, sweaters and the working hours were less, hence it was more conducive than summers. Yet the first floor spaces were very cold in early morning hours and later afternoon due to their direct exposure of the external surface walls to winter breeze and lead to even very cold spaces. Here in few instances, it was observed that two session students were combined in one class to enable it had more energy generated from the students presence and in some time it became bearable. Though this solution was limited only incase where ample classes were happening simultaneously. An overall comparison of both seasons temperature averages is shown below in figure 11.

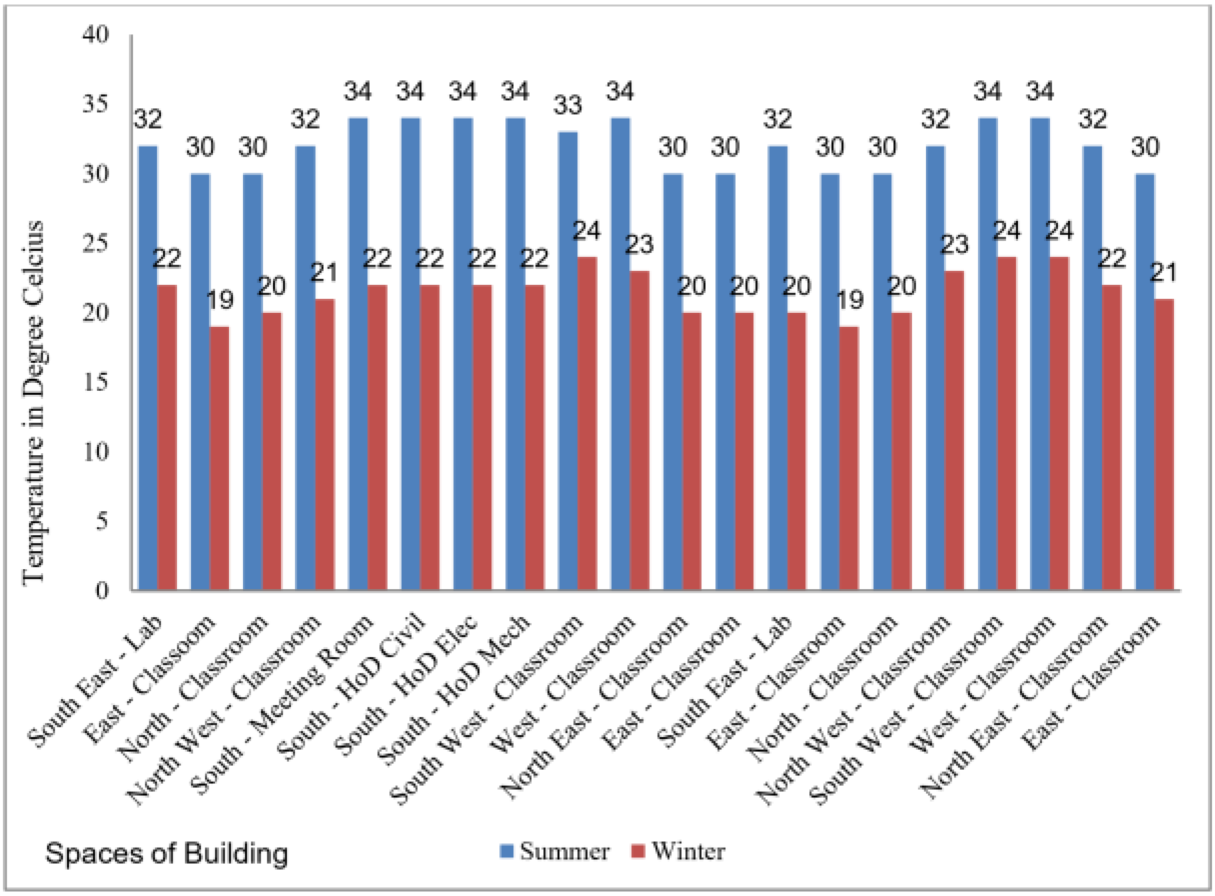

Figure 11 Temperature comparison of both seasons

As shown above in the figure 11, the contrasting averages between summer and winter season could be observed where the comfortable range of 24^{o} Centigrade on average is missed in both the seasons. Respondents data for summer season and winter season is shown below:

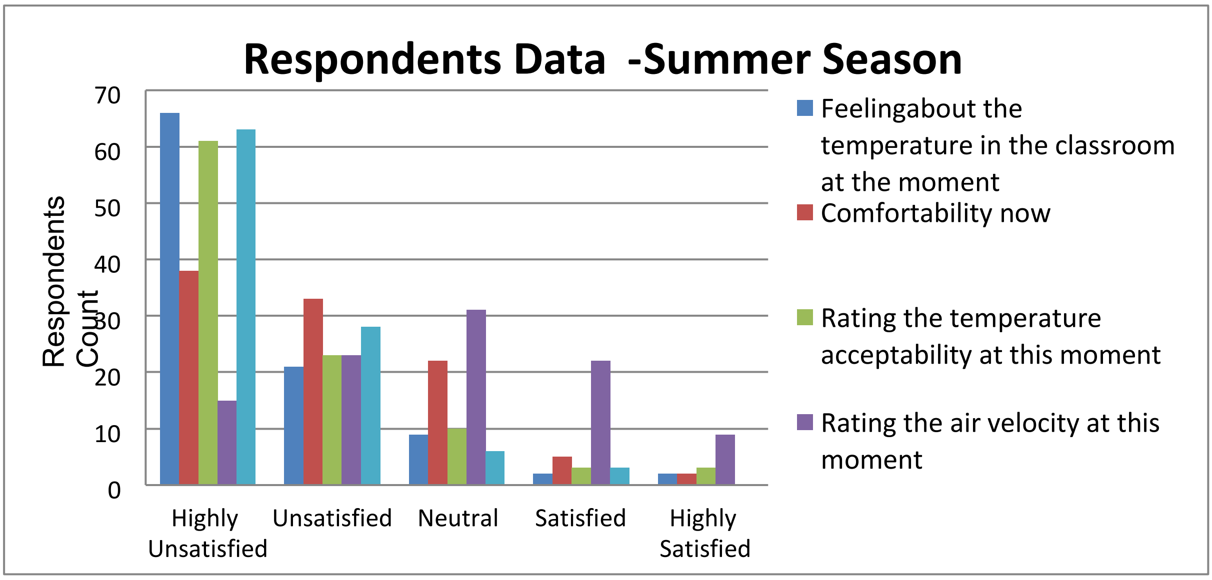

Figure 12 Respondents Summer Data

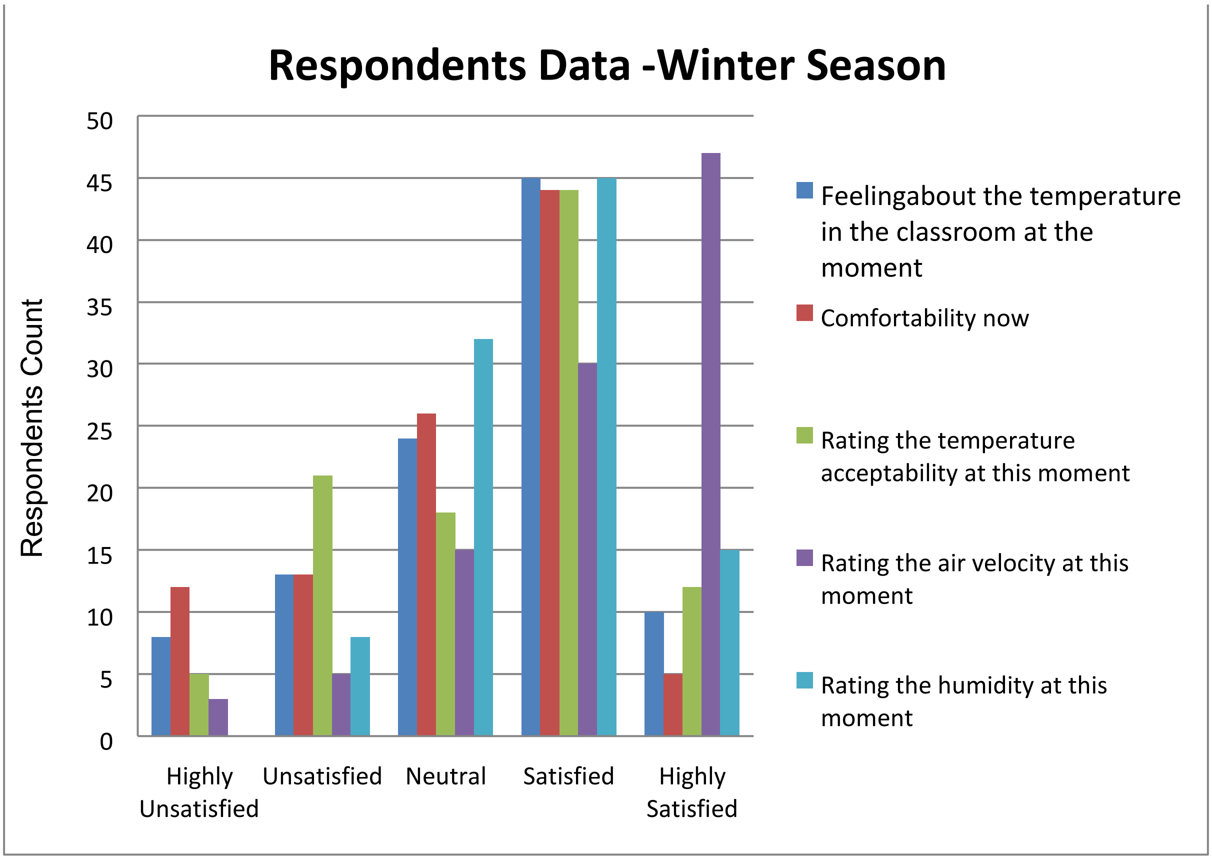

Figure 13 Respondents Winter Data

As shown in figure 12, the data collected from the respondents in the summer highly correlated with the observational study done by the researcher previously. As evident 66% were highly unsatisfied with the temperature they were feeling at the time data was collected. While asking about the feeling of comfort, 38 % were highly unsatisfied while 33% were unsatisfied with 88% wanted it to be cooler. Their temperature acceptability mainly was 61% highly unsatisfied and 23 % unsatisfied in the current moment when asked. With respect to air velocity and cross ventilation, there were 23% unsatisfied while 31% felt it was neutral or acceptable with no major impacts. It was 63% highly unsatisfied and 28% unsatisfied while inquired about the humidity level of satisfaction. As shown in figure 13, overall respondents consider winter season as more comfortable as compared to summer season in the building. 45% were satisfied with the current temperature in the room while 24% found it neutral and had no negative impact on them. It was also evident that 44% were satisfied with the comfort level. Yet it was a bit more confusing that 97% still wanted it to be a bit more warmer. It was later asked from respondents about this aspect, which highlighted that due to heavy clothing though they feel comfortable but a bit more warmer would feel them more better while they may remove their jackets. Above 60% were feeling satisfied with the current temperature state. It was highly appreciated by many in the form of 47% that the windows and ventilators were closed in winters and hence it was comfortable. Though 45% were satisfied with the current humidity level in the spaces, it was also observed that this variable was not much significant to the respondents since most of the spaces were closed with respect to opening in the windows and exposed sides. Only natural light was allowed which helped manage the temperature better in the spaces where direct sunlight had better penetration.

Hence it was evident that the thermal comfort aspects were found to be satisfactory amongst the respondents in the Winter season of the same selected building. Respondents were satisfied with the current building performance with respect to the thermal comfort. It was considered as more comfortable to the faculty as well in the winter season as compared to the summer. Inferential data for Summer & Winter season using Mean, Median, Mode and Standard deviation is shown below:

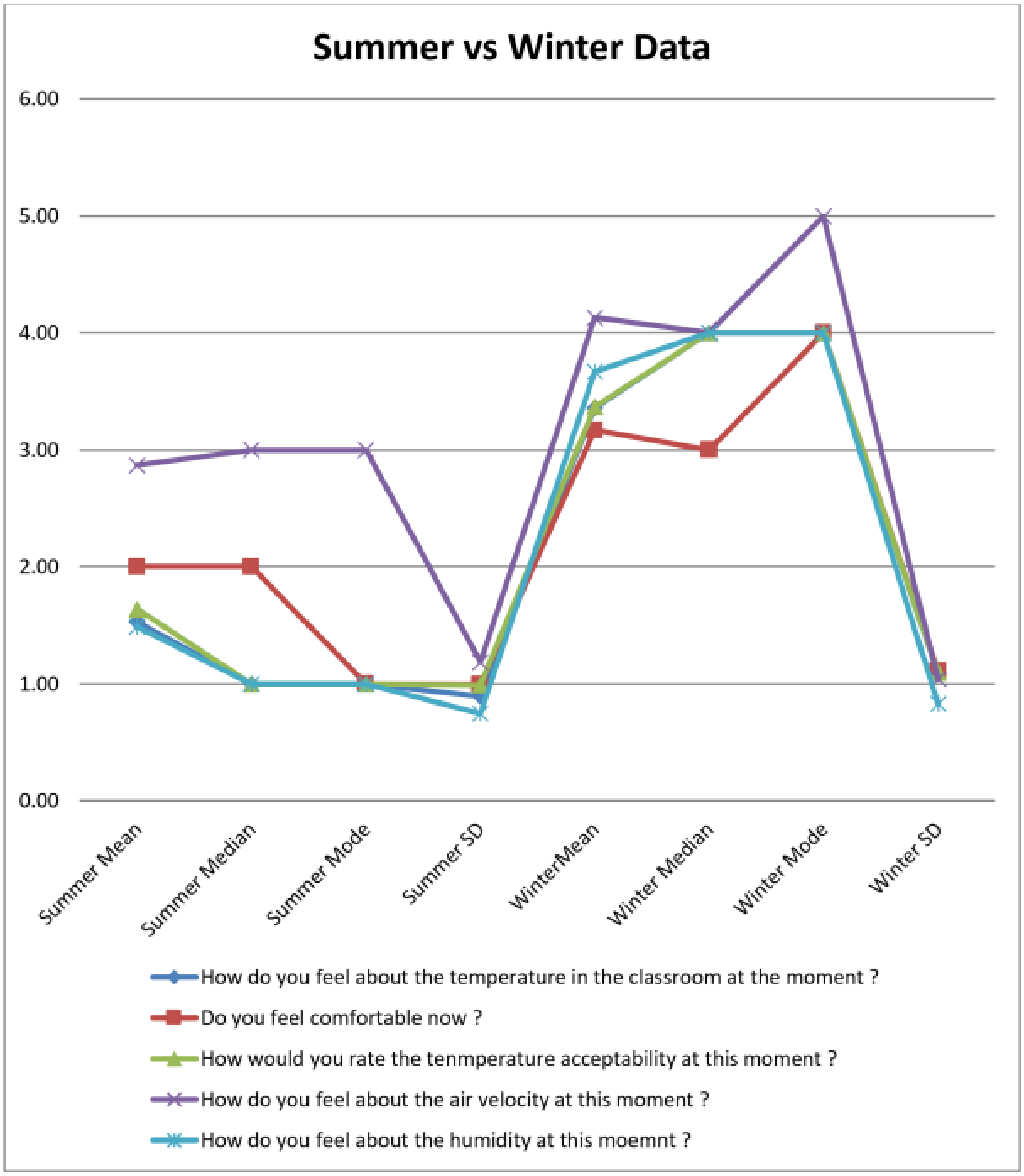

Figure 14 Summer vs Winter inferential data comparison

Based on the discussion with respondents during data collection phase, it was observed that students prefer to opt for ground floor in both seasons since it was less exposed to direct sun heat gain in summer while also not having direct roof exposure in winters. Students prefer to opt for small classrooms in the winter season while opted for larger size classrooms in the summer season. The major reason was due to cross ventilation and reduced humidity when a lot of students sit in the same room. Students did preferred to opt for North –Eastern setting of spaces in summer due to higher ambient lighting yet avoiding direct solar exposure while South was the only side preferred mainly in winters. West was also anticipated during the discussions but due to short day length, by the sun reaches the West side, the exposure is very less and for few hours which causes no major environmental benefit to students in the indoor spaces.

Research Findings & Conclusions

As discussed above, in summers, out of 100 respondents 66 were highly unsatisfied with temperature while 88 wanted the temperature to be more cooler. 61 respondents also showed highly unsatisfied with current temperature acceptability, cross ventilation and air velocity was acceptable while humidity was also highly unacceptable to 63 respondents. In winter season, 45 respondents were feeling satisfied with temperature while 24 were neutral. Same was the case in overall comfort however existing conditions. Here the respondents data study lead to better acceptability and utilization of the explored spaces by the users in the winter season as compared to the summer season. Respondents acknowledged that higher ceiling level helps to manage the heat in the spaces as number of students is high but due to poor cross ventilation and less operational windows, humidity also rises and hence creates discomfort. One of the major finding was that based on the observational study and discussion with the teachers and old staff members, it was clear that no insulation what so ever was not provided in the building walls, roofs or any other external façade members.

One of the basic reason of the building poor performance was the planning of the overall building in one unit while multiple blocks could have been developed. With much longer and comparatively severe summers, spaces with less occupancy could have been on the South, West and South – Western sides. Better utilized and preferred spaces were mainly East, North and North- Eastern spaces. It was also concluded that adding higher ceiling height but not enhancing cross ventilation or air velocity had negative impact on the end user satisfaction and usage of the space. Apart from orientation, lack of insulation in walls and roof also created some of the major issues related to thermal comfort by adding and raising the internal temperatures in the explored spaces and creating occupancy issues. Though ceiling height was high, 12’-0” yet ventilators were provided in few rooms while others didn’t have them.

It was recommended that in future building should opt for with adding student and higher usage spaces on the North, East and North – Eastern sides while less functional, less occupancy and circulation spaces could be added on the West, South & South – Western sides in the context of Narowal city. Façade and shading devices should be improved after proper contextual analysis. Proper insulation in walls and on roof top be provided along with enhancing cross ventilation through forced mechanical means where applicable. Timeline based recommendations are stated below:

Table 03 - Timeline based recommendations & strategies

S.No	Recommendation / Strategy	Timeline
01	Building orientation & solar analysis.	Long term strategy for future buildings.

02	Building façade	Short term to moderate term with immediate line of action in the context for the explored building while optimization for allied buildings after similar studies.
03	Roof Insulation	Short term and immediate to be done so that by next seasons, building performance and user satisfaction could be improved.
04	Wall insulation.	Immediate and short term action required. Walls facing the East, West and South sides can have additional insulation installed form the inside of the building using Thermopore or Styrofoam sheets with plaster finish. This will increase the thermal lag
05	Windows resizing	Moderate term. Semi-circular windows should be replaced with rectangular windows and their sizes must be 1/4th of the total room size as per rule of thumb.
06	Ventilation enhancement.	Short term to moderate term with immediate line of action in the context for the explored building while optimization for allied buildings after similar studies.

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