The Measured and Perceived Impacts of Environmental Conditions on Cadet Performance of Written Assessments

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INTRODUCTION

As the preeminent leadership institution in the world, the United States Military Academy at West Point is charged with educating, training, and inspiring future leaders of character. Every day, over 4,400 Cadets undergo rigorous military, physical, and academic training. In terms of academics, the Cadets study topics ranging from philosophy to electrical engineering, to law to environmental science. However, the facilities in which this learning takes place are often not reflective of the level of education being conducted.

West Point is currently in the middle of a facilities upgrade with the primary focus being placed on the Cadet barracks; their living quarters where they spend the majority of their time. Once complete, the renovation of the academic buildings will commence. However, until that occurs, 21st century learning will be taking place in 20th century buildings. For example, Washington Hall, which houses the Departments of Military Instruction, Foreign Languages, and Geography and Environmental Engineering was constructed in 1964 and has not undergone a renovation since.

Many things have changed since the building's construction in 1964. Classroom technology has evolved markedly and deserves discussion, but that is an issue for another time.
Focus need also be applied to the infrastructure of the building itself. The current HVAC system in Washington Hall has not been altered since the building's inception. The majority of the classrooms rely on window-unit air conditioners, resulting in significant climate variations from classroom to classroom. Variable such as geographic orientation, the number of windows, and interior or exterior location exacerbate these differences. Both instructors and Cadets remark about the relative discomfort that some rooms foment, particularly during the beginning of the academic year.

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), which the U.S. Army complies with, indicates that indoor temperatures should be between 73°F and 79°F in the summer months and 68°F and 79°F in the winter (ASHRAE, 1992). Although classroom temperatures generally fall within this range, it is not uncommon for temperatures to deviate from it, particularly towards the warmer end of the spectrum. What impact these temperature perturbations might have on Cadet academic performance?

Past research indicates that classroom temperature impacts student performance. When evaluating standardized test scores of fifth grade students, researchers found that there was an increase in math, science, and reading scores that correlated with a decrease in temperature from 77°F to 68°F (Haverinen-Shaughnessy and Shaughnessy, 2015). Wargocki and Wyon (2007) found that 10-12 year olds indicated increased comfort when classroom temperature was reduced from 77°F to 68°F and produced significant improvement in completion speed of numeric and language based tests. Similar results were found in other studies of school age children, where decreased temperatures correlated with increased performance (Aulicems, 1972; Wyon, 1970).

Findings extend beyond school-aged children and do not necessarily indicate that cooler temperatures are preferable, but rather that classroom temperature does play a factor. Pepler and
Warner (1968) found in a study of Kansas State University students that error rate was greatest at 62°F and decreased until a temperature of 80°F was reached. However, students worked slowest at 80°F and fastest at 68°F. When researching working conditions in office buildings, it was determined that performance increased up to 72°F and then began to decrease when 75°F was reached. At 86°F performance decreased 9% from optimal (Seppenen et al., 2006). Wyon (2007) found that typewriting efficiency in adult subjects decreased as temperature was increased from 68°F to 75°F.

Clearly, temperature variation correlates to performance in a wide variety of subjects, performing a wide variety of tasks, but to what extent? One study of university students found that thermal comfort affected performance similarly to air quality and visual environment, but auditory environment played the biggest role in performance (Lee et al., 2012). Similarly, while conducting a meta-analysis of research already performed, Hancock (2007) determined that task type, exposure duration, and thermal intensity were key variables in determining how thermal conditions affected performance.

The question at hand thus seem to naturally pose itself. Do classroom environmental conditions, in terms of temperature, affect Cadets' performance and/or their perception of their performance?
METHODS

This study was initiated in August of 2017 and completed in December of 2017. The study design centered on measuring the classroom temperature which Cadets were subject to, Cadets' performance on various graded events, and the Cadets' perception of the classroom temperature and its subsequent effect on their ability to perform on the aforementioned graded event.

Test subjects were selected as all Cadets that took EV203 (Physical Geography) and EV300 (Environmental Science) in the fall semester of 2018. EV203 was selected because of its large sample size, all Cadets must take EV203, and EV300 was selected because of its large sample size, all Cadets taking the Environmental Engineering sequence must take EV300. Also, both of these classes are conducted in Washington Hall, which has a particularly varying range of classroom temperatures.

Temperature was measured in all rooms that held classes of EV203 and EV300. This consisted of 15 different classrooms on the sixth floor of Washington Hall. All of the classrooms had windows; some had functioning window unit air conditioners and some did not. Window unit air conditioners were not all of the same make and model. The classrooms were dispersed through three different wings of Washington Hall, thus experiencing different aspects of solar radiation for different durations of the day. Temperature was measured using an Onset HOBO data logger, model U10. Data loggers were placed next to the computer monitor in each of the classrooms. Although the classrooms are generally set up the same way, some data loggers could have been closer to air conditioning units than others, and vice versa. Temperature was
recorded every five minutes for the duration of the study. Data was downloaded using HOBOware software.

Two graded events were selected for analysis during this study. The entire course of EV203 took four quizzes during the duration of the semester. These quizzes were proctored in the same rooms that the Cadets had class in each day. Tests were proctored in different rooms. For these reasons, the four quizzes in EV203 were selected as being the graded events to be analyzed for evaluation of Cadets performance. Similarly, the entire course of EV300 took two Written Partial Reviews (WPRs), which are analogous to a test or exam, during the duration of the semester, and these WPRs were proctored in the same rooms that the Cadets had class in each day. The two WPRs were selected as being the graded events to be analyzed for the evaluation of Cadet performance. Cadet grades on aforementioned quizzes and WPRs were obtained from the respective Course Director.

Cadet perception of classroom temperature and its subsequent effect on their performance during the graded event was determined using a three question survey (Figure 1). Due to timing constraints, the survey was given to Cadets in EV203 after the third and fourth quizzes and Cadets in EV300 after the second WPR. The survey was voluntary, and Cadets took the survey immediately following the graded event. Instructors collected the surveys after completion and gave them to the researchers of this study for analysis.

Microsoft Excel was used to conduct data analysis. Analysis included the following: the mean temperature of a given classroom during a graded event, the mean score (as a percentage) Cadets in a given classroom received on a graded event, the mean comfort level (via survey) Cadets experienced in a given classroom during a graded event, the mean extent to which Cadets felt temperature impacted their performance (via survey) in a given classroom during a graded event.
event, and the mean change in temperature (via survey) Cadets felt a given classroom
necessitated to ensure optimum comfort. Simple linear regression was used to determine any
relationship between these variables. In order to account for discrepancies in academic abilities
between different students, an analysis of variance (ANOVA) was conducted on the CEER score
(used to evaluate each Cadet entering West Point) and there was no significant difference
between any of the difference classes that met in the various rooms and various times.
Classroom Comfort Survey

Room Number & Hour ________________

1. How comfortable was the classroom temperature today?

1 – Uncomfortably Warm  
2 – Comfortable  
3 – Uncomfortably Cool

2. To what extent do you think the room temperature impacted your quiz/test performance?

1 – No Impact  
2 – Minor Impact  
3 – Major Impact

3. How do you think the room temperature should be changed to ensure optimum comfort?

1 – Warmer  
2 – No Change  
3 – Cooler

Figure 1. Example of the survey given to Cadets in EV203 and EV300 following graded events to evaluate their level of comfort with regards to classroom temperature, preferred change in temperature, and possible impact temperature may have had on their performance during a graded event.
RESULTS

The WPR data set consists of two WPRs worth of data (to include WPR score, temperature, and survey results), from eleven sections (analogous to a particular class meeting at a particular time in a particular room) each, for a total of 22 mean WPR scores and temperatures. Surveys were given only after the second WPR of the semester, thus the data set consists of eleven mean survey results. The quiz data set consists of 4 quizzes worth of data (to include quiz scores, temperatures, and survey results), from 33 sections each, for a total of 132 mean quiz scores and temperatures. Surveys were given only after the third and fourth quizzes of the semester, thus the data set consists of 66 mean survey results.

Analysis was conducted using linear regression. Linear regression analysis produces a P-value, which comments on the correlation between the predictor value and the response variable. P-values less than or equal to 0.05 demonstrate a meaningful relationship between the predictor value and the response variable. P-values greater than 0.05 suggest that changes in the predictor values are not associated with changes in the response value. Linear regression does not establish causation, but merely indicates correlation.

Upon completion of linear regression analysis for the WPR data set, only three of eleven relationships evaluated had P-values less than 0.05, indicating correlation (Table 1). The P-value for the predictor value of mean comfort score and response value of mean WPR score was 0.0267. The P-value for the predictor value of mean perceived impact of the climate conditions and the response value of mean WPR score had a P-value of 0.0335. The P-value for the predictor value of mean desired temperature change and response value of mean WPR score was 0.03. There was no correlation between either temperature or relative humidity and WPR score.
Table 1. Linear Regression for the possible correlation between 5 different predictor values and 4 different response values during WPR analysis.

<table>
<thead>
<tr>
<th>Predictor Value</th>
<th>Response Value</th>
<th>P-Value</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Temperature</td>
<td>Mean WPR Score</td>
<td>0.7323</td>
<td>No</td>
</tr>
<tr>
<td>Mean Relative Humidity</td>
<td>Mean WPR Score</td>
<td>0.6347</td>
<td>No</td>
</tr>
<tr>
<td>Mean Comfort Score</td>
<td>Mean WPR Score</td>
<td>0.0267</td>
<td>Yes</td>
</tr>
<tr>
<td>Mean Perceived Impact Score</td>
<td>Mean WPR Score</td>
<td>0.0335</td>
<td>Yes</td>
</tr>
<tr>
<td>Mean Temperature Change Score</td>
<td>Mean WPR Score</td>
<td>0.03</td>
<td>Yes</td>
</tr>
</tbody>
</table>

| Mean Temperature                       | Mean Comfort Score        | 0.7699  | No          |
| Mean Relative Humidity                 | Mean Comfort Score        | 0.6598  | No          |

| Mean Temperature                       | Mean Perceived Impact Score| 0.4414  | No          |
| Mean Relative Humidity                 | Mean Perceived Impact Score| 0.7644  | No          |

| Mean Temperature                       | Mean Temperature Change Score| 0.0919  | No          |
| Mean Relative Humidity                 | Mean Temperature Change Score| 0.9179  | No          |
Mean classroom comfort scores ranged between 1.71 and 2.06, indicating that Cadets' comfort levels were slightly uncomfortably warm to comfortable (Figure 2). Mean WPR scores ranged between 75% and 91%. There was a negative correlation between the two variables. Classes that reported a general discomfort due to warmth had higher mean WPR scores. Increasing comfort correlated with lower WPR scores. The two lowest mean WPR scores, 75% and 81% were found in classes that reported a mean classroom comfort level of two, which indicates being comfortable.

Mean perceived temperature impact on WPR performance was between 1.13 and 1.69, indicating that cadets perceived temperature to have more than no impact on their performances, but less than a minor impact on their performances (Figure 3). A positive correlation existed between these two variables. Classes that had mean impact scores closer to one, indicating temperature having no impact, scored lower on the WPRs, while classes that had mean impact scores closer to two, indicating that temperature had a minor impact, scoring higher on the WPRs. The section with the lowest score, 75%, report a perceived impact of 1.13, which correlates to virtually no impact.

Mean preferred temperature change had a low value of 2 and a high value of 2.67, indicating that cadets were generally comfortable with the temperature and wanted to no change to preferring that the temperature were cooler (Figure 4). A positive correlation existed among this data, with classes who wanted to change the temperature to be cooler performed better on the test. The class that had the lowest mean WPR score, 75%, reported a preferred change value of two, which was no change. This same class indicated that the classroom was comfortable and reported the lowest perceived impact that temperature had on their performance.
Figure 2. Comparison between the mean temperature comfort level for a particular room during a particular hour and the corresponding mean WPR score for a particular room during a particular hour. Classroom temperature comfort is calculated as the mean of all reported values on a scale of: 1=uncomfortably warm, 2=comfortable, and 3=uncomfortably cool. WPR score is calculated as the mean of all scores. Solid line represents a linear regression between the two variables. The equation is the equation of the linear regression and the $R^2$ is that of the linear regression.

$$y = -0.2461x + 1.3045$$

$R^2 = 0.437$
Figure 3. Comparison between the mean temperature impact for a particular room during a particular hour and the corresponding mean WPR score for a particular room during a particular hour. Impact is calculated as the mean of all reported values on a scale of: 1=temperature has no impact on performance, 2=temperature has a minor impact on performance, and 3=temperature has a major impact on performance. WPR score is calculated as the mean of all scores. Solid line represents a linear regression between the two variables. The equation is the equation of the linear regression and the $R^2$ is that of the linear regression.
Figure 4. Comparison between the mean preferred temperature change for a particular room during a particular hour and the corresponding mean WPR score for a particular room during a particular hour. Preferred temperature change is calculated as the mean of all reported values on a scale of: 1=warmer, 2=no change, and 3=cooler. WPR score is calculated as the mean of all scores. Solid line represents a linear regression between the two variables. The equation is the equation of the linear regression and the $r^2$ is that of the linear regression.

$$y = 0.1551x + 0.4887$$

$R^2 = 0.4239$
Following linear regression analysis of the quiz data set, it was again determined that three of the 11 relationships tested exhibited a correlation that resulted in a P-value of less than 0.05 (Table 2). However, correlations did not exist between the same relationships for the quiz data set as existed for the WPR data set. The P-value for the predictor value of mean perceived impact of the climate conditions and the response value of mean quiz score was 0.00965. The P-value for the predictor value of mean temperature and the response value of mean perceived comfort was \(2.248 \times 10^{-10}\). The P-value for the predictor value of mean temperature and the mean desire for temperature change was \(1.629 \times 10^{-9}\). There was no correlation between either temperature or relative humidity and quiz score.

Mean temperature impact scores were between 1.1875 and 1.94, indicating that Cadets felt that temperature had relatively no impact on their performance to just below a minor impact on their performance (Figure 5). No classes felt that the temperature had more than a minor impact on their performance. Mean quiz scores ranged between 54% and 86%. Conversely to the WPR data set, a negative correlation existed between mean perceived impact and quiz score. Classes that perceived the temperature having a greater impact on their performance, generally scored lower on their quizzes.

A negative correlation also existed between mean temperature and mean reported classroom comfort (Figure 6). Temperatures ranged between 65°F and 85°F, with cadets generally reporting rooms being uncomfortably warm the higher the temperature rose. At 65°F Cadets did report being uncomfortably cool, with a mean score of 2.35. A positive correlation existed between mean temperature and mean preferred change in temperature (Figure 7). The warmer the classroom was, the cooler the Cadet's preferred the classroom to be. At 85°F, Cadets reported a preferred change of 2.83, indicating that nearly all cadets would prefer it cooler.
Table 2. Linear Regression for the possible correlation between 5 different predictor values and 4 different response values during Quiz analysis.

<table>
<thead>
<tr>
<th>Predictor Value</th>
<th>Response Value</th>
<th>P-Value</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Mean Quiz Score</td>
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<td>No</td>
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<td>Mean Relative Humidity</td>
<td>Mean Quiz Score</td>
<td>0.0915</td>
<td>No</td>
</tr>
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<td>Mean Comfort Score</td>
<td>Mean Quiz Score</td>
<td>0.7205</td>
<td>No</td>
</tr>
<tr>
<td>Mean Perceived Impact Score</td>
<td>Mean Quiz Score</td>
<td>0.00965</td>
<td>Yes</td>
</tr>
<tr>
<td>Mean Temperature Change Score</td>
<td>Mean Quiz Score</td>
<td>0.3168</td>
<td>No</td>
</tr>
<tr>
<td>Mean Temperature</td>
<td>Mean Comfort Score</td>
<td>&lt;0.00001</td>
<td>Yes</td>
</tr>
<tr>
<td>Mean Relative Humidity</td>
<td>Mean Comfort Score</td>
<td>0.1037</td>
<td>No</td>
</tr>
<tr>
<td>Mean Temperature</td>
<td>Mean Perceived Impact Score</td>
<td>0.2088</td>
<td>No</td>
</tr>
<tr>
<td>Mean Relative Humidity</td>
<td>Mean Perceived Impact Score</td>
<td>0.659</td>
<td>No</td>
</tr>
<tr>
<td>Mean Temperature</td>
<td>Mean Temperature Change Score</td>
<td>&lt;0.00001</td>
<td>Yes</td>
</tr>
<tr>
<td>Mean Relative Humidity</td>
<td>Mean Temperature Change Score</td>
<td>0.102</td>
<td>No</td>
</tr>
</tbody>
</table>
Figure 5. Comparison between the mean temperature impact for a particular room during a particular hour and the corresponding mean quiz score for a particular room during a particular hour. Impact is calculated as the mean of all reported values on a scale of: 1=temperature has no impact on performance, 2=temperature has a minor impact on performance, and 3=temperature has a major impact on performance. Quiz score is calculated as the mean of all quiz scores. Solid line represents a linear regression between the two variables. The equation is the equation of the linear regression and the $R^2$ is that of the linear regression.
Figure 6. Comparison between the mean temperature for a particular room during a particular hour and the corresponding temperature comfort level for particular room during a particular hour. Temperature is calculated as the mean measured value during the class period. Classroom temperature comfort is calculated as the mean of all reported values on a scale of: 1=uncomfortably warm, 2=comfortable, and 3=uncomfortably cool. Solid line represents a linear regression between the two variables. The equation is the equation of the linear regression and the $r^2$ is that of the linear regression.

\[ y = -0.0456x + 5.1737 \]

$R^2 = 0.5284$
Figure 7. Comparison between the mean temperature for a particular room during a particular hour and the corresponding preferred temperature change for particular room during a particular hour. Temperature is calculated as the mean measured value during the class period. Preferred temperature change is calculated as the mean of all reported values on a scale of: 1=warmer, 2=no change, and 3=cooler. Solid line represents a linear regression between the two variables. The equation is the equation of the linear regression and the $R^2$ is that of the linear regression.

\[ y = 0.0547x - 1.6649 \]

\[ R^2 = 0.4931 \]
DISCUSSION

In this study, no linear correlation existed between WPR or quiz score and the ambient air temperature in the classroom during the proctoring of said graded event. This result was unexpected, especially due to the fact that the recorded temperatures in this research (ranging from 65°F to 89°F) were outside the range of what past research found to be impactful temperatures (68°F to 77°F) (Haverinen-Shaughnessy and Shaughnessy, 2015 and Wargocki and Wyon, 2007). Nonetheless, points worthy of discussion still exist.

First, there were no correlations between mean relative humidity and any other measurement. Thus, the Cadets seemed much more in tuned in the temperature of the classroom rather than the relative humidity. This is likely do the Cadets tending to perceiving comfort or discomfort from temperature, while being much less aware of humidity expect in extreme conditions not likely to be found in a classroom. Although relative humidity exhibited no correlations, temperature did.

The quiz data exhibited a linear correlation between mean temperature and mean desire for temperature change and between mean temperature and mean comfort level. This indicates that Cadets were aware of their climatic surrounding (being too hot or too cold) and were able to report it as such. Wargocki and Wyon (2007) reported similar findings. No such correlation between mean temperature and mean desire for temperature change was indicated in the WPR data, for which the linear regression analysis had a P-value of 0.0919. The quiz data set contained six times as much data as the WPR data set. The P-value for the WPR set was very low and only 0.0419 away from the significance mark of 0.05. Thus, due to the proximity of the
WPR set P-value to the significance mark and it relatively low sample size, there is a high likelihood that a correlation would exist upon further inspection.

There was a correlation between mean comfort score and the mean WPR score, however it was a negative correlation. The Cadets who reported being uncomfortably warm performed better on the WPR than the Cadets who reported being comfortable. This finding does not mesh with the results of past research that indicates when people are uncomfortable due to temperature, they generally perform worse. It should also be noted that there was not a correlation between Cadets' comfort level and temperature. So, the comfort level Cadets reported was not entirely driven by the ambient temperature. The possible conclusion from these results, is that the actual temperature does not correlate to WPR score or comfort, but perhaps Cadets' perception of environmental variables does, which can affect comfort and thus performance. The temperature data collected mostly stayed within the seasonal comfort boundaries, so this does not appear to be an unreasonable conclusion.

The linear correlation between mean desire for temperature change and mean WPR score reinforces this conclusion. The data indicates a positive correlation between the Cadet's desire for temperature change and their mean WPR score. Cadets who are comfortable with the climate conditions tended to perform worse on WPRs than those who were unsatisfied with temperature and humidity. This data ties in with the conclusion above that the individual perception of climatic comfort is more important than the actual climatic conditions. However, this seems contrary since those that were uncomfortable and wanted the temperature to change performed better.

The quiz data analysis did not show a correlation between the desire for temperature change and the mean quiz score. This correlation existed with the WPR data set. This conflict is
likely due to the nature of each assessment. WPRs are 55 minute long complex assessments. Quizzes are shorter assessments, covering limited topics. They do not require the same level of concentration, focus, or preparation. Thus, it appears as though the climate impact manifests more so with the assessments of longer duration and complexity.

There was a correlation between the perceived impact of the climactic conditions and the mean WPR score. The Cadets that reported their climate comfort impacting their performance actually performed better. This seems to be an inverse of a self-fulfilling prophecy. Those Cadets who perceived discomfort and a possible setback actually performed better.

Similarly to WPRs, the results for the analysis of the quiz data indicate a linear correlation between the mean perceived impact of the climactic conditions and the mean quiz score. However, in the instance of quizzes, those Cadets that perceived temperature having an impact on their performance performed more poorly. This is in direct contrast to the impact-score correlation that existed in the WPR data set. Possible explanations exist for this disparity.

First, it should be noted that the population of Cadets enrolled in EV203 was approximately 50% plebes (freshman) and 50% yearlings (sophomores) while the population of Cadets enrolled in EV300 was approximately 90% yearlings and 10% cows (juniors). A cadet's first year at the academy is starkly different than an undergrad's first year at a traditional college or university. Plebes have just completed six weeks of Cadet Basic Training, which indoctrinates them to the ways of the Military Academy. During their first semester, plebes are still trying adjust to the military lifestyle, college-level courses, and the other countless stressors that are placed upon them. It is possible that this could play a driving factor in the results of this research.
At the United States Military Academy, Cadets wear uniforms. Uniforms are strictly prescribed and minimal departures are authorized. As a result, the populations studied were unable to alter their wardrobe in response to dissatisfaction with the temperature. Thus, the wear of uniforms likely amplified the impacts of an individual’s dissatisfaction with the temperature in a classroom which impacted their performance. This would be especially true for plebes and be portrayed in the negative correlation between impact and score in the quiz data. Yearlings on the other hand have had a year to adjust to the idea of wearing uniforms. This could be why the same correlation was not evident in the WPR data.

Another possibility could be traced to the training conducted at West Point. The military focuses heavily on training soldiers to be resilient. Cadets are educated about how to maintain resilience through difficult situations. They are indoctrinated to accomplish the mission no matter what circumstances they are faced with. Perhaps after a year of training, the yearlings have already become more resilient than the plebes. The WPR data (dominated by yearlings) indicated that those that thought temperature would impact their performance scored higher. Possibly, these Cadets felt their back against the wall and were able to adjust, overcome, and still perform well. Conversely, the quiz data (dominated by plebes) indicated the opposite. This population has not been trained in resilience as extensively as the previous. This could be reason for perceived temperature impact more negatively affecting their scores.
CONCLUSION

This study demonstrated a correlation between the mean of students surveyed comfort level and their mean WPR Score. It appears as though the comfort level does not impact shorter, simpler quiz scores. For both data sets, there was a correlation between mean perceived impact and mean examination score. However, one was a positive correlation while the other was a negative. But, Cadets do appear to be aware of the climactic impacts on the test scores.

Based on this analysis, administrators and teachers can generally see an improvement in Cadets' performance by increasing their comfort with respect to temperature. In the case of Washington Hall, this means investing in a modern HVAC system with thermostats in each classroom. It is generally too hot in Washington Hall for the preference of students. Teachers should also considering adjusting uniform rules for long and complex graded events, such as WPRs. Experimentation will be required to validate this postulation, however the data demonstrates a correlation worth examining with future work.

Lastly, students seem to be aware of the impact of their perception of temperature and humidity on performance. Teachers must endeavor to discuss this with students and see what is within their power to affect to improve student comfort. Also, Research has indicated that learner attitude and motivation are the most vital components to their success (McDaniel and Brown, 2014). If educators can portray the fact that outside factors, such as climatic comfort, or really non-factors, students could likely perform to their highest potential.
REFERENCES


