A Study of Thermal Performance of Contemporary Technology-Rich Educational Spaces

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ABSTRACT

One of the most dominant features of a classroom space is its high occupancy, which results in high internal heat gain (approximately 5 KW). Furthermore, installation of educational technologies, such as smart boards, projectors and computers in the spaces increases potential internal heat gain. Previous studies on office buildings indicate that with the introduction of IT equipment in spaces during the last decade, cooling load demands are increasing with an associated increase in summer electrical demand. Due to the fact that educational technologies in specific correspond to pedagogical practices within the space, a lot of variations due to occupancy patterns occur. Also, thermal loads caused by educational technologies are expected to be dependent on spatial configuration, for example, position with respect to the external walls, lighting equipment, mobility of devices. This study explores the thermal impact of educational technologies in 2 typical educational spaces in a facility of higher education; the classroom and the computer lab. The results indicate that a heat gain ranging between 0.06 and 0.095 KWh/m2 is generated in the rooms when educational technologies are in use. The second phase of this study is ongoing, and investigates thermal zones within the rooms due to distribution of educational technologies. Through simulation of thermal performance of the rooms, alternative room configurations are thus recommended in response to the observed thermal zones.

Keywords: Learning Technologies, Performance-based Design, Thermal Performance, Learning Spaces, Heat Gain.

1. INTRODUCTION

Occupied with students and equipped with educational technologies, classrooms and laboratories are considered the basic unit for thermal comfort and energy consumption in educational buildings. Equipment in these spaces become significant sources of sensible and latent heat, which need to be lowered in order to reduce the energy consumption in the facilities. Existing literature and findings for low energy consumption in other building types (for example residential or office buildings) thus may not apply to educational spaces, where occupancy patterns are different, as well as the nature and patterns of use of technologies, and accordingly, internal heat gains.

Previous research has only emphasized the importance of high performance design of a school classroom disregarding the role of educational technologies as relates to thermal performance of the spaces [1][2][4][8]. Studies conclude that through enhanced design of building components such as walls and openings, school buildings might consume 180 to 80 kW h/m2 for heating, cooling, ventilation and lighting annually in hot-humid climates. This means a reduction of more than 50% of the energy consumption than typical designs[8]. These results match those found in high performance schools in Europe and US, with 55–75% savings in heating and 30–40% savings in electricity when several technologies were implemented as part of a holistic approach aiming at high energy savings and accepting medium and long payback times [8]. There is no study found in the literature which investigates the thermal impact of using learning technologies in contemporary learning environments. This study aims to bridge this gap. Two typical room configurations have been selected for investigation; a classroom, and a computer lab. The rooms are diverse in size and proportion, layout, and equipped with a variation of learning technologies.

2. EXPERIMENTAL SETUP

Two rooms were selected as a sample in a facility of higher education in the city of Al Ain, United Arab Emirates. The building typically lies in the hot arid climate. Measurements were taken in the months of November and December, where the ambient outdoor temperatures typically lie between (---). During this time of the year the facility is at its highest occupancy level and usage rates of educational technologies. However, temperature measurements were taken when the room not occupied, the results thus represent only the thermal impact of educational technologies on the space. Also, air conditioning was shut down whenever measurements were taken in the rooms. However, it should be noted that thermal conditions in both rooms vary during the day with the variation in solar radiation which they are exposed to from the east oriented facades.

The rooms represent the typical configurations of a classroom (Figure 1), and a computer lab (Figure 2). The first is equipped with a smart board system located at the front learning wall. The second is equipped with 22 desktops; 10 on two perimeter walls, as well as 12 in the center. The learning wall at the computer lab constitutes of a smart board system, and the front teaching zone is also equipped with a desktop and a printer (Figure 4). While the classroom is only equipped with a smart board mounted on the front learning wall (Figure 3).

Temperature measurements in both rooms were recorded on a central axe starting from the learning wall to the opposite external façade of the room (which in both rooms was facing east) as illustrated in Figure 3 and Figure 4. The height of the temperatures sensors were set at the occupants' level and accordingly, were fixed on the lower surfaces of the desks.

Figure 1: Spatial Configuration of Classroom Sample

The measurement points were evenly distributed across the room on a central axe. Measurements were taken at equal intervals of 1.5 m starting from the point below the heat source (smart board projector) and along the measurement axe towards the east external walls.

Measurements in both rooms were recorded between 7:00 a.m.-7:00 p.m. daily; typically the hours in which the facility is occupied.

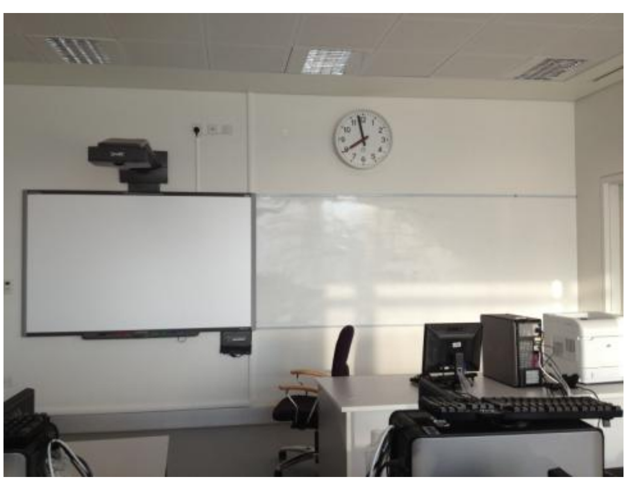

Figure 2: Spatial Configuration of Computer-Lab Sample

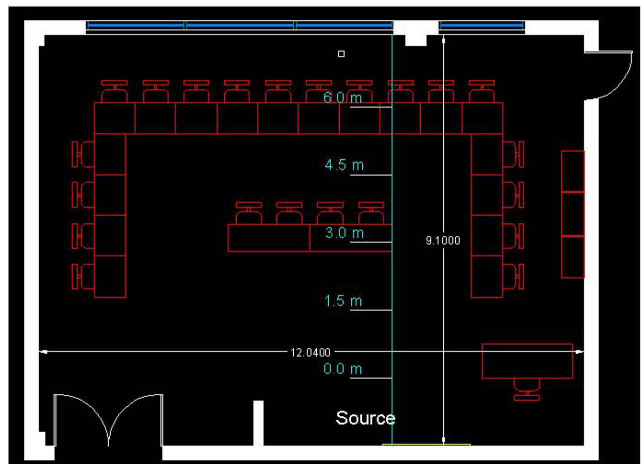

Figure 3: Measurement Points Across the Classroom

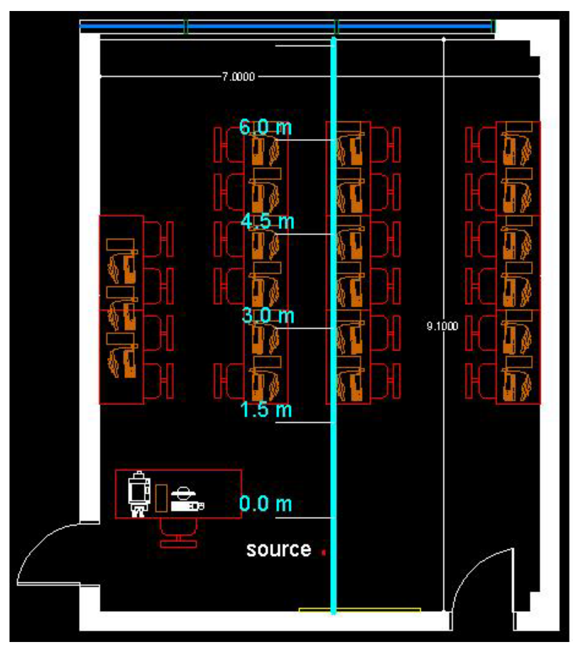

Figure 4: Measurement Points Across the Computer-Lab

3. METHODS

Temperature measurements collected are grouped in 4 data clusters for each room:

1) Morning interval temperatures with the technologies on (T_{on}): temperatures collected between 7:00 a.m. and 3:00 p.m. with all educational technologies in the room turned on.
2) Morning interval temperatures with the technologies off (T_{off}): temperatures collected between 7:00 a.m. and 3:00 p.m. with all educational technologies in the room turned off.
3) Afternoon temperatures with the technologies on (T_{on}): temperatures collected between 3:00 and 7:00 p.m. with all educational technologies in the room turned on.
4) Afternoon temperatures with the technologies off (T_{off}): temperatures collected between 3:00 and 7:00 p.m. with all educational technologies in the room turned off.

Phase one: temperature measurements are obtained to calculate the heat gain in the spaces due to full operation of educational technologies available in each room. A/C was not in use during experimentation. Also, the rooms were not occupied.

Heat gain in the room due to educational technologies was calculated based on the following equation:

$$Q = m' \, C_p (T_{on} - T_{off})$$

$$Q = \rho \, V' C_p (T_{on} - T_{off})$$

$$V' = \frac{ACH \; x \; V}{3600}$$

Where:
m' = mass flow rate of air
V' =Volume flow rate of air
C_p = heat capacity of air
T_{on}= Indoor air temperature while technology is on
T_{on} = Indoor air temperature while technology is off
ρ = Air density
ACH= Air changes per hour (5ACH)

Equation (1): Heat Gain Calculations.

Figure 5 illustrates temperatures when the single smart board in the classroom is turned on, while Figure 6 illustrates a sample of temperatures measured in the same room with no educational technologies are in use. With an air volume of 229.3 m^3, total heat gain in the classroom of area 109.56 m^2, was found to reach 6.47 KWh, which is equivalent to 0.06 KWh/m^2. With an average rise in temperatures that reached 3.7°C due to the use of educational technologies in this room configuration.

Educational technologies in the computer lab on the other hand, with air volume of 0.32 m^3 and area 63.7 m^2, resulted in total heat gain of 6.03 KWh, which is equivalent to 0.095 KWh/m^2, with an average rise in temperatures that reached 4.5°C due to the use of educational technologies in this room configuration. Figure 7 and Figure 8 illustrate the temperature data gathered at the computer lab in both room conditions; with educational technologies turned on and off.

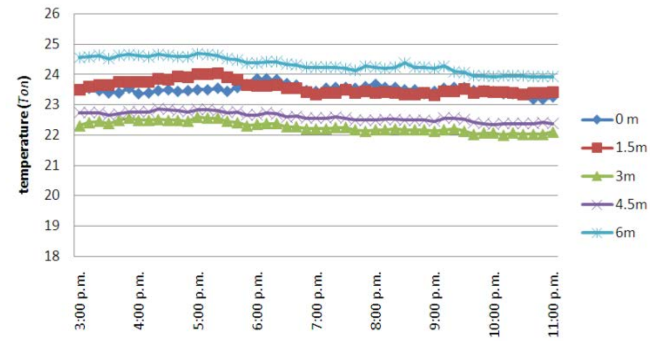

Figure 5: Sample of Temperature Measurements (T_{on}) at 5 Data Input Points in the Classroom. Afternoon Interval, Educational Technologies Turned On.

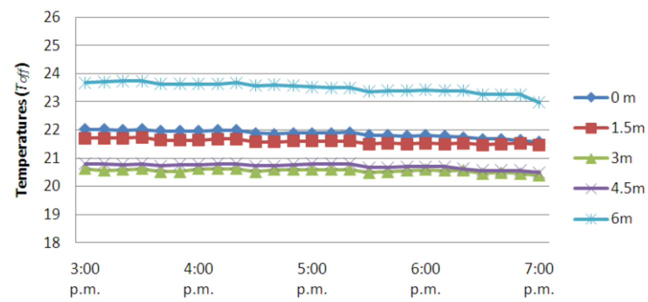

Figure 6: Sample of Temperature Measurements (T_{off}) at 5 Data Input Points in the Classroom. After noon Interval. Educational Technologies Turned Off.

It is observed from the thermal data obtained across the depth of both rooms, that the even distribution of the technologies has influenced the thermal profiles of each room. Thus a potential effect on user's thermal comfort may be

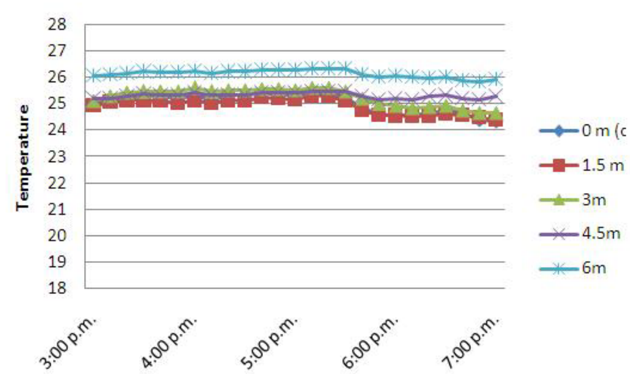

Figure 7: Sample of Temperature Measurements (Ton) at 5 Data Input Points in the Computer-Lab. Afternoon Intervals. Educational Technologies Turned Off.

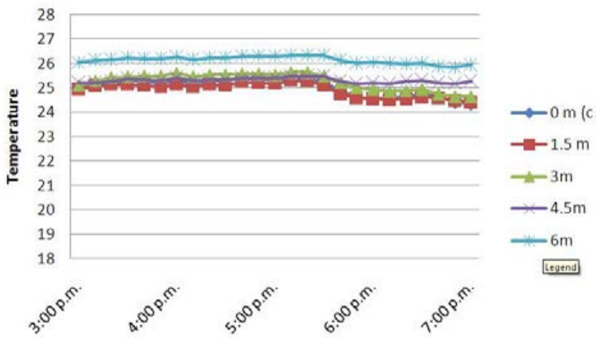

Figure 8: Sample of Temperature Measurements (Toff) at 5 Data Points in the Computer Lab. Afternoon Intervals. Educational Technologies Turned Off.

Phase two: The second phase of this study is ongoing and aims at investigating thermal profiles of the rooms as relates to the distribution of educational technologies and the influence on users' thermal comfort.
For that, each room is divided into 3 thermal zones:

1) The educational front zone: in which the typical instructional process takes place, and includes the learning wall and instructor's work station.
2) The learning zone: students occupy most of this zone, most educational technologies in the computer lab is also occupying this central area.
3) The perimeter zone: is mostly influenced by the external envelope conditions, solar radiations and wall composition. In classroom situations, the effect of learning technologies at the front zone is minimal.

In that phase, thermal zones in both rooms are simulated. And compared to alternative proposed configurations Recommendations for room configurations achieving better thermal performance and thermal balance within the spaces conclude the study.

4. CONCLUSION

In contemporary learning spaces, learning technologies play an important role in thermal performance of such spaces. The study investigates 2 typical spaces in a higher education institute; a typical classroom and a computer lab. Both rooms vary in proportion, type and number of learning technologies, as well as their distribution within the space.

During the experiment, air conditioning in the room was turned off, and the rooms were not occupied.

Thermal zones and profiles observed varied with the distribution of educational technologies in each room. Also, there has been proven rise in room temperatures and heat gain in the room.

With an area of 109.56 m^2, heat gain in the classroom resulting from a single smart board mounted on the front learning wall was found to be 0.06 KWh/m^2. With an average rise in temperatures that reached 3.7°C. Educational technologies in the computer lab on the other hand, with area of 63.7 m^2 resulted in total heat gain of 0.095 KWh/m^2, with an average rise in temperatures that reached 4.5°C due to the use of educational technologies in this room configuration.

The study also investigates thermal zones within the rooms due to distribution of educational technologies. Room configurations are thus recommended in response to the observed thermal zones.

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