Chapter 1: Introduction

Modern life has invalidated the traditional way of life of our grandparents when most of their time was spent outdoors in the field. With the massive current level of industrialization and urbanization, most work has shifted indoors where people work in factories to produce commodities or make transactions either through paperwork or digital modes. This has resulted in most of the time being spent indoors, whether at home or at work. Indoor conditions involve air, materials, lighting, ventilation, air-conditioning, noise, odor, decoration and surfaces. All of them should be made available in the ideal amount in order to create a comfortable environment for living, studying, playing or working. About a few decades ago, almost all buildings were exposed to the outside environment, and all interior elements were an extension of the outside environment. Rooms were ventilated and lighted naturally. In today's buildings however, things have changed, and a building has become an individual unit isolated from outside effects. They are constructed from steel and glass and are isolated with their ventilation systems built in self-contained units.

Through this study, the researcher aims to investigate the effect of incorporating interior green wall in indoor educational spaces and its impact on the IEQ of classrooms and students' learning, by using measuring equipment to evaluate the surrounding indoor atmosphere. This will be followed with a survey which will be conducted among students and lecturers in order to assess their class performance and productivity levels.

Living inside such isolated buildings have led to several manifestations such as fatigue, drowsiness, lack of energy, dizziness, nausea, irritation, headache and other symptoms which are not related to specific physical illness. This has been called Building Related Illnesses or BRI. (Lee et al, 1996). Such symptoms have drawn the attention of experts to diagnose the case and find out what indoor factors lead to them. Several solutions were proposed, one of which is the use of plants indoors (IEQ indoor plants n.d.).The idea of common plants solving Indoor Air Quality (IAQ) problems is familiar to most people, as they like having plants in their homes, offices and public buildings they visit. Previously many researchers have studied the effect of green built environment on IAQ.

Research has proved that Indoor Environmental Quality (IEQ) issues are connected with air pollutants and thermal qualities such as thermal comfort quality, sound quality, light quality, odour quality and air quality. Further, it has been noted that plants are a reasonable method for indoor air pollution control such as its effect on air, thermal, and sound in a space, as well as its influence on the sensory systems of the human body.

A green wall is a different design technique that allows the designer to indicate a large number of plants in a space which can affect an indoor classroom environment more positively. It is a way to attract the attention of occupants to the presence of plants and works as good visual items which will positively affect their performance and productivity. Interior green walls can survive more than exterior green walls especially in hot climates like the UAE, which will enhance indoor environments in a simple and inexpensive way.

1.1 Research Problem

The research will evaluate the feasibility and impact of integrating interior green wall in a university classroom setting in terms of its influence on sensory systems of the human body which will in turn affect the students' learning performance (in calculating, reading, understanding designing and drawing). All this data will be evaluated against standard educational classrooms. Furthermore, the research will test green walls in classrooms as a way of improving indoor environments as well as its technical construction and assess which type of plants can be used. It specifically aims to answer the following questions:

1. Do plants have the potential to actually affect indoor air sufficiently in order to warrant their use as air cleaners?
2. What amount of plants is required in the space to remove indoor air pollutants as effectively as normal air exchange in a particular space?
3. Does the presence of indoor plants in a place affect students' performance and productivity whether in an office, classroom or home?

1.2 Objectives of the Study

This study aims at finding out whether green walls inside classrooms affect students' comfort and performance. It seeks to attain the following goals:

- Identifying the benefits in comfort by using indoor plants, such as: thermal, acoustical and visual comforts by analyzing students' responses to the questionnaire.
- Providing an overview of the different kinds of indoor plants that can be used in a UAE indoor environment and the possible configurations of green wall system.
- Determining the varying parameters of green wall-like orientation, the percentage of plant area coverage relative to the façade wall and classroom space.

- Analyzing the impact of interior green wall on classroom indoor climatic conditions as well as its reflection on student's performance and their outcomes.

1.3 Significance of the Study

As the UAE is placing increasing emphasis on education and investing in human resources, it has built modern schools and provided them with all the educational facilities to ensure the success of the teaching process. The findings of this study may be illuminating for policy-makers who are putting in a constant effort to improve teaching conditions. Insights can be drawn from this study with regards to making indoor plants a standard part of interior design due to their positive effect. Given the fact that there have been no previous studies on this topic before, this study might draw more attention to this neglected aspect of the educational environment.

1.4 Out-line of the study.

This study will follow the following approaches:

1. Qualitative approach. This will be done by reviewing related literature and previous studies. It will also be the method employed in explaining the phases of the experiment.
2. Experimental approach. This will be followed when assessing the impact of green wall inside the classroom.
3. Quantitative approach. This will be employed in measuring the parameters of indoor environments in addition to analyzing the responses to the questionnaire posed to the subjects of the experiment.

Chapter 2: Literature Review

The modern way of life has driven people (especially in urban areas) to spend most of their time indoors. Therefore, it has become of greater importance to make the indoor environment comfortable and healthy. There are several aspects of interior environment like lighting, calmness, visual items, and air quality that can be considered. But this study is concerned primarily with one aspect, which is the use of plants in classrooms. It has been found that interior plants affect air cleanliness, air temperature, humidity and relaxation. In other words, it is affirmed that plants absorb pollutants, increase humidity through the vapor they produce, and pleases the senses enabling people to relax. Figure 2.1 shows Standard 55, Thermal Environmental Conditions for Human Occupancy where an occupant lives in an environment with the right temperature and humidity level (Energy-design-tools.aud.ucla.edu, 2014) the green area represents the comfortable zone.

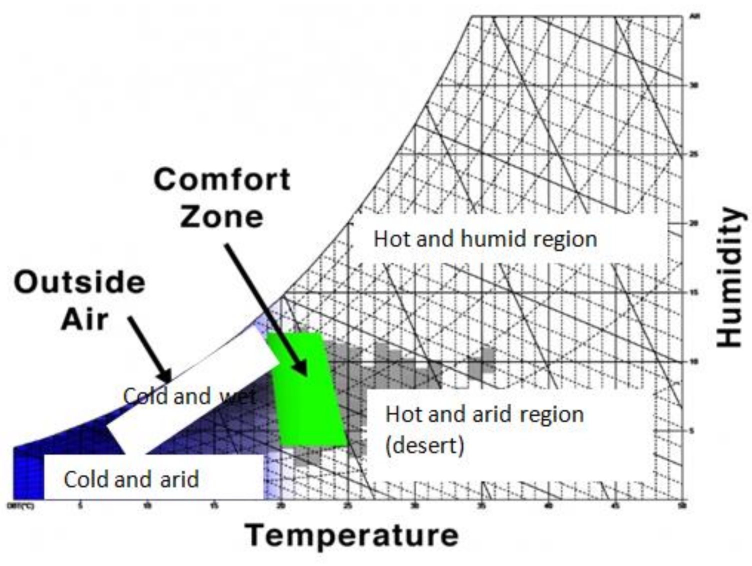

Figure: 2. 1: Thermal Environmental Conditions for Human Occupancy, (Energy-design-tools.aud.ucla.edu, 2014).

Indoor pollutants are of four types: organic, inorganic, particulates, and biological matters. Organic matters are hydrocarbons which are the most common pollutants indoors. Inorganic pollutants are chemical compounds like NO_2, CO, CO_2, SO_2 and O_3. Particulate matters are inorganic compounds like dust, smog, mist and smoke. Biological pollutants are bacteria, viruses, pollen, moulds and dust mites. (Lee et al, 1996). Such pollutants do not directly affect the human body, but a person does feel uncomfortable and not well enough to perform his duties efficiently.

There are several measures that can be taken to make an indoor environment healthy, like the removal of pollutants, allowing natural ventilation and lighting, in addition to putting plants indoors. It is an undisputed fact that plants emit oxygen and help purify the air and this makes suburban areas and plains healthier places to live in. Several studies have suggested that plants indoors have a positive impact on relaxation, attention and concentration. Some studies on employees suggested that plants increased the level of job satisfaction.

In general, plants have obvious benefits for the human body and mood. (Tree People, 2014). These benefits include:

1. Alleviating the impact of global warming by absorbing CO_2 and releasing O_2 into the air, thus removing the layer that traps heat in the earth's atmosphere.
2. Absorbing odors and pollutants like nitrogen oxides, ammonia, sulphur dioxide and ozone.
3. Filtering air by trapping particles in the leaves and bark.
4. Cooling air by the shades plants make and through the evaporation process.

5. Saving energy required for cooling and consequently reducing the emission of CO_2 produced by power plants.

As shown in Table 2.1, there are direct benefits and indirect benefits for indoor plants. The common view of indoor plants is that they are an object of beauty whereas in fact, they have more functions. Basically, they refresh the air by releasing oxygen and absorbing carbon dioxide. They humidify the air by vapour as a result of heat absorption by leaves. In this way, they reduce the need for air-conditioning and the cost of energy. Plant leaves absorb pollutants and purify the air which allows for healthier respiration. So, cleaner air, thermal stability, and a beautiful scene contribute towards physical and mood stability which in turn results in an increase of productivity and performance improvement.

Table 2.1: Indoor plants benefits (Ambius, 2014)

Indoor Plants Contribute To At Least 75% Of Indoor Environmental Quality (IEQ) Criteria

IEQ criterion	Indoor Plants
Air pollution mitigation	Reduce all types of urban air pollution
Low Emitting Materials	Absorb toxic emissions - VOCs etc
Ventilation effectiveness	Increase effectiveness - remove CO2/add O2
Lighting	OK for Plants - OK for staff also
Noise	Absorb & buffer noise
Views	Add aesthetics & calming greenery; lower stress
Thermal comfort	Not directly influenced but tend to stabilise humidity in human comfort zone, so could have unquantified effects here
Systems controllability	Not directly influenced but stabilisation of temperature and humidity could lower air-con. energy consumption

IEQ Indoor Plants define several benefits for indoor plants at workplace:

(Ieqindoorplants.com.au, 2014).

1. They improve the performance of school children
2. They increase productivity at the workplace by 12%.
3. They increase employee retention by improving employees' perceptions and dispositions.
4. They clean air which leads to a healthier environment with a lower concentration of volatile organic compounds.
5. They improve the quality of indoor life in terms of aesthetic stimulation and relaxation
6. They improve corporate image
7. They reduce stress
8. They reduce sick leave
9. They boost comfort level
10. They increase the level of job satisfaction
11. They enhance employees' learning

In 2004, the University of Guelph-Humber Building in Ontario installed a 4-storey biowall irrigated by a vertical droponic system. The university reported that the plant wall which was visible in every floor acted like a cooling system, purifier and humidifier. Dr. Ron Wood, Professor Margaret Burchett and others in Australia say "we now know that several common species of interior landscape plants have the ability to remove compounds such as benzene and hexane in the range of 50% to 75% of the total volatile organic compounds. To ensure sustainability of the urban environment, satisfying the 'triple bottom line' of environmental, social and economic considerations, it is expected that indoor plants will become standard technology--a vital building installation element, for improving indoor air quality." (Green Plants Benefits, 2014)

In 1998, a US coalition of leading industries formed a council called Leadership in Energy and Environmental Design (LEED). The purpose of this council was to enhance building practices that promote environmentally adequate buildings in terms of energy and water consumption and internal environment quality (IEQ). The LEED IEQ category addresses six criteria: indoor air quality (IAQ), low-emitting materials, indoor chemical and pollutant source control, controllability of systems, thermal comfort, daylighting and views. (Lee and Guerin2009). This interest in green buildings stems from the belief that green buildings can have a long-term financial return when occupants' satisfaction and productivity improves.

2.1 Standard Internal Environment.

The table below defines the limits that if pollutants exceed, they can harm human health to a great extent. These limits are set by different international associations. Some of the standards are designed for home occupation and some are defined for workplace safety.

Whether via natural circulation of air or through mechanical means (forced ventilation as part of the heating or air conditioning system), ventilation is an important quality parameter for indoor environment, both for comfort and safety. This is to ensure the occupants are breathing fresh air for comfort. For safety, the United States Occupational Safety and Health Administration (OSHA) have regulations in place to define a safe environment for living and working. The regulation defines the allowable limits for contaminants based on a 24 hour exposure. These limits represents the maximum that can be allowed, however, most countries and even states within the USA adopt stricter regulations based on their own environments and what is reasonably achievable. The table below shows the OSHA regulations for air contaminants along with a comparison to the ASHRAE guidelines. It is worth noting the difference between guideline and a regulation limit here. A guideline is a recommendation to follow while a regulation is a limit enforceable by law.

Internal environments should meet certain standards in order to be a healthy and comfortable place to live and work in. Some of these standards were set by the American Society of Heating, Refrigerating and Air-conditioning Engineers Inc. (ASHRAE), while others were set by the Illinois Department of Public Health, Occupational Safety and Health Administration and American Conference of Governmental Industrial Hygienists. What is relevant to this study is the parameters set by ASHARE as they define conditions for living and studying and not at the work place. So, ASHARE's criteria are the criteria for comparison in this study. As seen in Table 2.2, the humidity level is defined by 30-60. If it exceeds this limit, it is considered to be annoying and conducive to the growth of bacteria and dust mites and aggravate asthma.

Table 2.2: Pollutants limits for "Healthy Indoor Environment" (Idph.state.il.us, 2014)

PARAMETER	IDPH	ASHRAE	OSHA PEL *	ACGIH TLV **
Humidity	20% - 60%	30% - 60%	N/A	N/A
Temperature	68° - 75° (winter)	68° - 75° (winter)	N/A	N/A
	73° – 79° (summer)	73° - 79° (summer)		
Carbon Dioxide	1,000 ppm	1,000 ppm	5,000 ppm	5,000 ppm
	(<800 ppm preferred)			
Carbon Monoxide	9 ppm	9 ppm	50 ppm	25 ppm
Hydrogen Sulfide	0.01 ppm	N/A	20 ppm	10 ppm
Ozone	0.08 ppm	N/A	0.1 ppm	0.05 ppm
Particulates	0.15 mg/m^3 (PM 10) (150 µg/m^3) 24-hr 0.065 mg/m^3 (PM 2.5) (65 µg/m^3) 24-hr	N/A	15 mg/m^3 (total)	10 mg/m^3 (total)
			5 mg/m^3 (resp.)	3 mg/m^3 (resp.)
Formaldehyde	0.1 ppm (office)	N/A	0.75 ppm	0.3 ppm
	0.03 ppm (home)			
Nitrogen Dioxide	0.05 ppm	N/A	5 ppm	3 ppm
Radon	4.0 pCi/L	N/A	100 pCi/L	4 WLM/yr (working level months/year)

Most countries have their own standards and guidelines to specify a comfortable and healthy indoor environment. In the United States for example, there are several regulatory agencies and professional societies concerned with occupational health and safety. Each of these agencies and professional societies have defined allowable limits on pollutants for indoor environments. Exceeding these limits might be considered unlawful in cases when these limits were issued by government agencies with jurisdiction and power of the law to enforce these limits. In other situations the limits are simply guidelines that are not enforceable by law.

In Table 2.2 there are four different entities that have issued limits on indoor pollutants to define a healthy and safe environment. Two of these four entities are government agencies that have the power of the law to enforce their limits. The other two are professional societies that issue guidelines that are recommended but not enforceable. The first of the government agencies is the Illinois Department of Public Health. From the name of the agency one can glean that its jurisdiction is limited to the state of Illinois and it is mentioned in the table only because the table was copied from its website. It is interesting to note here that IDPH can issue limits but these limits cannot exceed the limits issued by the federal agencies like OSHA (Occupational Safety and Health Agency, which is a U.S. federal government agency with jurisdiction over all states including Illinois), as can be readily noticed from the table in the third column.

The third column in the Table 2.2 belongs to the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) which is a professional society for engineers working in the field of heating, air conditioning and refrigeration. It is a nongovernment organization that among many other activities related to their field of interest; issues guidelines to define a comfortable indoor environment, but these are only recommendations. ASHRAE being a professional and recognized society, their recommendations are highly regarded and in many cases referenced as requirements by builders, other professional societies and even some regulatory agencies. However, as can be seen from the table, the ASHRAE recommendations are limited to the comfort of the environment and they do not issue guidelines for the safety of the environment as safety is not their specialty.

The fourth column in Table 2.2 is another nongovernment professional society that issues recommendations for both comfort and safety. The American Conference of Governmental Industrial Hygienists (ACGIH) is a well-respected organization by individuals in the industrial hygiene and occupational and environmental health and safety industry. It is one of the oldest non-government organizations in this field with a presence in many countries outside of the USA. ACGIH issues recommendations on health and safety in a wide range of fields including agricultural safety and health, air sampling instruments, biological exposure indices and industrial ventilation. Like ASHRAE, the recommendations made by ACGIH are highly regarded around the world but they are not enforceable by laws.

An equivalent set of regulations and guidelines exist in many countries around the world. To organize things and facilitate international trade, the International Organization for Standardization (ISO) issued its own guidelines for indoor environment; the “ISO 16814”.

After all, Table 2.2 has a list of the most important parameters that define a comfortable indoor environment with values (range of values) that should make most of the people feel comfortable. The reason the table defines a range of values is that people are individuals and the temperature that suites one person might be too cold or too warm for the next person. In fact, the most common complaint received by heating and air conditioning technicians is that the temperature in the office is too cold. The second most common complaint for the same environment is that the temperature in the office is too warm. So, a comfortable environment is defined as the conditions that make 80% of the occupants feel comfortable. Below is a discussion of the parameters that affect indoor environments.

- Humidity: OSHA and ACGIH do not have regulation regarding the level of humidity for indoor environment because they are primarily concerned with safety and humidity which do not have strong implications on the health of the occupants as much as it affects their comfort level. A recommended level of humidity is set by ASHARE and IDPH. As seen in the table, humidity level is defined by 20-60% relative humidity. Relative humidity is defined as the amount of moisture in the air compared to the maximum amount of moisture the same volume of air can hold at the same temperature. When the maximum amount of humidity is exceeded, condensation starts to take place. If the humidity level exceeds these two boundaries, it is considered to be annoying and conducive to the growth of bacteria and dust mites and can even aggravate asthma.
- Temperature: The range of temperatures that is considered comfortable is rather wide and ranges from 68°F to 79°F. From the definition of "relative humidity" above, it is clear that there is a close relationship between relative humidity and temperature. The higher the temperature, the more moisture air can hold, and the same amount of moisture is felt as less humidity when it comes to comfort. The two parameters (humidity and temperature) are tied and ASHRAE charts show these two ranges defining a two dimensional comfort zone. If an indoor environment is designed such that at any point in time the temperature and humidity are within this zone, then it is considered comfortable by 80% of the occupants. ASHRAE is the main professional society concerned with

heating and air conditioning in North America. ASHRAE has defined a comfortable indoor environment as the conditions under which 80% of the occupants say they are reasonably comfortable at any given point in time. This is accomplished by matching the temperature and humidity levels in the environment to the skin temperature and humidity level of the occupants. For humans, the skin temperature is between 23 to 25 degrees centigrade even though the blood temperature near the heart is 37 degrees. However, due to heat loss and the proximity from the blood stream, the skin temperature is lower. ASHRAE numbers are based on extensive research to define the comfort zone in terms of temperature and humidity for indoor environments. Their recommendations are used in textbooks for engineering students throughout the world. The summary of their recommendations is that a comfort zone has a temperature range between 68°F and 79°F (20°C and 26°C)

- Carbon Dioxide (CO2): This is a gas that is a natural component of atmosphere and its percentage in the atmosphere was stable up until the start of the industrial revolution at the beginning of the nineteenth century. The extensive use of fossil fuels have tipped the balance, and for the past 200 years the percentage of carbon dioxide has been increasing in the atmosphere. Carbon dioxide is an inert gas and at normal concentration it is harmless, however, at high concentrations it is harmful and causes shortness of breath. It can be found in higher concentrations than normal acceptable limits in living places where heating depends on space heaters or fire places and in work places where some manufacturing processes rely on fossil fuel-fired burners (like older casting houses that rely on coal burning) or mining companies where work activities are taking place in confined places underground. OSHA has put an upper limit of 5000 ppm (parts per million particles). Notice here that both the IDPH and ASHRAE have stricter recommendations than the OSHA regulation. However, the OSHA number is the only limit that can be enforced through a federal court while the IDPH limit can be enforced in local courts within the state of Illinois and the ASHRAE and ACGIH limits are just a recommendation that cannot be enforced.

Carbon dioxide is a green house gas, meaning that it traps heat and causes the earth's temperature to rise in what is known as "global warming". Governments and environmental societies are always trying to limit its emission.

The way to reduce carbon dioxide concentration is through efficient ventilation by natural circulation of air or through forced ventilation as part of the heating or air conditioning system. Ventilation is another quality parameter for indoor environment both for comfort and safety. The concentration of carbon dioxide can also be reduced by having indoor plants as plants breathe carbon dioxide during the night time in order to produce oxygen.

- Carbon Monoxide (CO): This pollutant is a gas that results from burning organic material like fossil fuel in poorly ventilated areas such that an incomplete oxidation reaction takes place and carbon (fuel) combines with only one oxygen atom instead of the normal burning process where a carbon atom combines with two oxygen atoms to produce carbon dioxide. Carbon monoxide can be found in houses that rely on wood or fossil fuel burning space heaters with poor ventilation and in some older industrial facilities and also in mines underground. This is a lot more dangerous than carbon dioxide and can lead to death in few minutes as it attaches itself to the hemoglobin in the blood and prevents it from releasing oxygen to living cells that need the oxygen to survive, effectively reducing the oxygen-carrying capacity of the blood. That is why the OSHA limit on carbon monoxide is only 50 ppm (compared to 5000 ppm for carbon dioxide). Carbon monoxide is odorless, tasteless and a nonirritant and hence difficult to detect and protect against. Many people have died because of inhaling carbon monoxide during their sleep because they left their coal, kerosene or butane burning space heater on before they went to bed. Many people also commit suicide by inhaling carbon monoxide by sitting in their cars while the car is running in their closed garages. The best way to protect against carbon monoxide is to avoid burning organic material in closed spaces and always have good ventilation.

- Hydrogen Sulfide (H2S): This is an extremely poisonous gas that accompanies natural gas and crude oil in the oil and gas industry and it is also released to the environment either by the decomposition of organic material in industrial facilities or as bacterial byproduct from sitting water and sewage systems. This gas is so poisonous to the point where one breath of high concentration hydrogen sulfide can kill an adult within just a few minutes. At very low concentrations (less than 10 ppm) hydrogen sulfide smells like rotten eggs but at slightly higher concentrations (100 ppm) it numbs the smelling nerves and cannot be smelled anymore, and at these concentrations (more than 100 ppm) it causes death through suffocation in less than a minute. This gas is a leading cause of sudden death in the work place especially in the oil and gas and petrochemical industries. Many examples are documented of industrial accidents where hydrogen sulfide caused the death of many workers like what happened in 1980 when a blowout occurred at an offshore drilling rig in the Gulf and caused the death of 19 men within minutes (Saudi Aramco pocket guide on health hazards 1980).

- Ozone (O_3): This is a blue colored gas that smells like chlorine. It consists of 3 atoms of oxygen O_3 (versus two atoms for regular oxygen O_2). It is used in few industrial applications and sometimes in air purifiers. It is used sometimes to treat respiratory problems because it destroys mucus. However, nowadays many medical doctors are recommending against the use of Ozone because of its damaging side effects on the respiratory system. Some bottled drinking water suppliers use it to give the water they sell a sense of cleanliness.
- Radon (Ra): This is a radioactive gas that emits alpha particles. When inhaled, Radon attaches itself to the lung tissues and continues to decay by emitting alpha particles inside the lungs causing damage to the lung tissues and eventually causing lung cancer. Radon gas attaches itself to tobacco leaves and becomes part of regular cigarettes. Along with smoke of cigarettes, it contributes towards the high lung cancer among smokers. Other sources of this radioactive gas are uranium mills (mines that produce uranium yellow cakes). If a country has uranium mines then most likely uranium dust is part of the soil downwind from the mine for several hundreds of miles; this is called the "uranium mill tail". If building materials are taken from a uranium mill tail zone (materials like sand, bricks, woods…etc. then it will contain uranium atoms which decay to produce Radon-222 gas). Radon is airborne and radioactive and emitted in poorly ventilated living spaces (especially basements in concrete buildings) its concentration will increase and exceed safe limits and if inhaled, it attaches itself to the lungs and continues to decay to produce radioactive lead (Pb-210), which has a half-life of 19.4 years and can lead to lung cancer. In the USA, in areas that have "uranium mill tail" testing for Radon gas contamination is mandatory prior to purchasing a new house. The testing process is rather elaborate and

takes more than 24 hours of compressing air through fine filters to trap Radon gas atoms, while in regions that do not have uranium mill tails, testing for Radon contamination is not required. (John Lamarsh, 1983.)

- Particulates: These are suspended solid particles in air that cause discomfort and have long term negative effect on the respiratory system. However, as the size of the particulates decreases they become carcinogens (like asbestos).
- Formaldehyde (CH2O): A gas used in petrochemical industries. Chronic exposure by workers to formaldehyde is considered carcinogenic and it also causes retardation and birth defects in infants.
- Nitrogen dioxide (NO2): This pollutant comes basically from car exhausts in a percentage of 80%, but it also comes from metal refining and coal-powered electrical power generating plants in addition to other industries. In living spaces, the sources of this pollutant are space heaters and cookers burning fossil fuel. This pollutant is particularly dangerous because it contributes to the formation of photochemical smog which is harmful to human health.

2.2 Classroom Environment.

Indoor environment in a classroom is different from other buildings because of the high density of occupants when compared to offices and other work places. This density has a direct influence on temperature, humidity, air quality and velocity. Another difference is that young people breathe more rapidly than adults. As they are mostly seated, they are more prone to inhaling pollutants closer to the ground. Therefore, they are more prone to having respiratory issues than adults. This makes a classroom environment an important field to research as it affects youngsters strongly. Indoor air quality is extremely important in a classroom as it affects students' behavior and academic performance. (Earthman, et al. 1995). Heath and Mendell (2002) point out that students who study in unhealthy air have a lower rate of attendance, productivity and performance. Unhealthy air quality results from several factors such as improper cleaning, inadequate heating or cooling, insufficient ventilation or an unacceptable humidity level. (Earthman, et al, 1995).

A student has to feel comfortable in terms of temperature, clean air, humidity, light, and level of sound.

2.2.1 Thermal comfort.

A student has to feel satisfied with the temperature surrounding him. This comfort results from the surrounding temperature, clothes, level of humidity and type of activity. Thermal comfort can be observed by simply monitoring the students' activities and restfulness. If they feel uncomfortable, they will complain or lose interest in taking part in a discussion or doing other class work. Educators have to ensure that there is no thermal stress if they want to enhance learning and active involvement. Chan and Petrie (1998) explains the effect of thermal stress on the brain saying that the sensory system sends signals to the brain about thermal stress and the brain responds by restricting its function. Schneider (2002) specifies ideal indoor temperature between 20 °C to 23 °C. If temperature is not within the acceptable range, the occupant will not exert an effort to adapt to it physically. (Cakir 2006) People normally adapt to temperature by adaptive behavior like modifying the level of activity, adding or removing clothes, or getting closer or further from the heat source. They may also adapt by removing the heat or cold source. The body itself adapts to external temperature by sweating in hot conditions or by forcing muscles and blood vessels to narrow or dilate to keep or release heat. If they cannot use the adaptive techniques, discomfort results (Nicol and Humphreys; 2001). Hussein and Rahman (2009) state that body surface temperature is 33 C°. Increase or decrease in heat level causes discomfort. This makes individuals feel exhausted and bad-tempered (New Zealand-Department of Labour, 2007). Students' performance will decline and they will feel stressed. But temperature interacts with other environmental conditions like humidity, air velocity, and level of activity. Therefore, adjusting room temperature should take into consideration these factors. Thermal conditions should be controlled well in a learning setting as they have a direct effect on students' mood and performance.

2.2.2 Air quality.

This refers to the cleanliness of air. Air can be polluted by CO, CO2, O3, and particulate matter.

a. Carbon monoxide.

Kleinmann (2000) states that metabolic rate among young people is higher than in adults, and they need a larger amount of oxygen in the process. If CO level is high, a child's growth is adversely affected and much exposure to this compound causes a decline in mental and memorization abilities. (Jain, 1999) CO has no color or odor or taste resulting from incomplete combustion. Inhaling CO for a long time can kill a human being by replacing oxygen in the blood and creating carboxyhemoglobin (COHb) The acceptable limit of COHb should not exceed 2.5%; otherwise, it causes hypoxia and affects the brain and body organs causing respiratory and cardiovascular problems. (Chichkova and Prockop, 2007) Lack of oxygen affects students' IQ and memory, and leads to hearing difficulties and depression. Occupational Safety and Health Administration (OSHA) set a standard for exposure to CO for workers not higher than 50 ppm for 8 hour length, while World Health Organization (WHO) advises 10 ppm for 8 hours. ASHARE defined it at 9 ppm for 8 hours. Chen et al (2000) proved that there is a relationship between students' attendance and CO level and found out that absenteismrates rise 3.79% for every 1 ppm CO increase in the elementary classroom.

b. Carbon dioxide.

The outcome of the breathing process is CO2. It is colorless and inflammable, but it can have an acidic taste and smell. But more important sources of CO2 are fossil fuel consumption and organic matter decomposition. CO2 is responsible for the greenhouse effect due to the emissions from different sources like industries and vehicles. Excessive inhalation of CO2 causes acidosis in blood which leads to problems in the central nervous system. (Canadian Centre for

Occupational Health & Safety (CCOHS)) Excessive amounts of CO_2 in the atmosphere leads to oxygen deficiency which is harmful to human health and causes asphyxia which occurs when oxygen ratio in the air becomes 16% or less. The deadly ratio of CO_2 is 40,000 ppm. (Illinois Department of Public Health (IDPH), 2011)

Students are also more prone to the inhalation of CO_2 especially if the classroom is crowded as a result of natural breathing. But indoor air is an extension to outside door environment and is affected by incoming air. So, if the outside air is polluted, the indoor air will also be polluted. However, the level of CO_2 inside the classroom is normally higher than outside.(Murphy and Bradley 2002) However, CO and CO_2 are not the only pollutants that adversely affect students. There are other pollutants like particulate matters which can result from different sources like the structure and age of the building, nature of internal activities, number of students, cleaning substances, exposure to external air which can carry particulates like dust inside and the HVAC system. (Fromme et al. 2007).

c. Ozone.

Ozone (O_3) has a bluish color when in high concentration and a strong odour. It is unstable and highly reactive. (EPA, 2010c). It has a vital function in the upper atmosphere as it protects earth from ultra-violet light, but when it is in the lower part, it is poisonous. Its concentration in the air varies from time to time and from one season to another (Long and Naidu, 2002). It is carried from outdoor to indoor through windows or air conditioners. Some electronic machines emit O_3 like photocopiers and laser printers. (Shaughnessy, 2006). It combines with other chemicals and produces harmful compounds. Ozone harms the central nervous system. (London Hazards Centre (LHC), 2002). If it combines with other pollutants like OH and RO_2, it can be irritating to the respiratory system and the eyes. It can also react with terpenes contained in cleaning substances and form formaldehyde. (Singer et al, 2006) Exposure to ozone for a long time can weaken lung function and make it vulnerable to other contaminants. In a classroom, ozone can come from ventilation or air conditioning and if the amount is over the acceptable limit and exposure is lengthy, students start to develop breathing problems and their performance is lowered.

d. Particulate matters

Particulate matters refer to solid or liquid matters hanging in the air. They can be organic and inorganic matters. They are generated by many human activities like industrial processes, agricultural operations, combustion of fossil fuels, construction procedures, and demolition procedures (Dimari et al., 2008) There are several sources of particulates. First, earth crust contains compounds such as sodium chloride, magnesium, sulfate, calcium, potassium and there are also sea spray aerosol which contains organic compounds. Second, there are gases resulting from oxidation like sulphuric acid and nitric acid. These normally result from combustion. There are organic particulate matters which come from air born pollen and volcanic eruption.(UNEP 2001)

Although particulate matters are pollutants, their effect depends on their concentration in the atmosphere. The concentration is usually measured by micro gram per cubic meter.

In the 1980‘s and 1990‘s, The National Ambient Air Quality Standards (NAAQS) suggested air quality standard for daily average PM10 is 150 µg/m3 and yearly mean is 50 µg/m3. In a classroom setting, particulate matters come from inside and outside the classroom like human activity, HVAC operating system, maintenance, age of the building and furnishing. (Fromme et al. 2007). In high concentrations, particulate matters have a hazardous effect on health. Dust is a major air pollutant and it endangers children's health at school. (Matz, 2000) Such particulate matters can cause severe respiratory problems and increases the rate of absence from school.

2.2.3 Humidity.

The best ratio of humidity inside a classroom is between 40%-70% according to Schneider (2002) although it is specified at 30-60% by ASHARE standards. If humidity levels rises, students feel uncomfortable and this affects their activity, performance and accomplishments. Body evaporation cooling declines when humidity level is high in the air, and a person is not able to reduce body heat. (Levin, 1995). So, if heat combines with humidity, individuals complain of discomfort. The optimal combination of temperature and humidity is 22.8 ^{o}C - 26 ^{o}C) with a relative humidity of 30-60%. According to Schneider (2002) the outcome of studies on thermal comfort determines that while RH and temperature level rise considerably, the students complain more about discomfort. In addition, their concentration level, performance and academic accomplishment decline. Students have a better performance in classrooms with RH in the range of 40% to 70% (moderate RH level) and indoor air temperature in the range of 68 °F to 74 °F (moderate indoor air temperature). They execute mental tasks more enhanced in classrooms that maintain temperature and humidity at moderate levels.

2.2.4 Air Velocity.

This refers to air motion across the body. It is necessary to create a thermal comfort as individuals are sensitive to air movement. Air movement enhances heat convection between the body and the environment. Air movement results from the ventilation system and body movement. In case the indoor environment has a low rate of air velocity, they feel uncomfortable and stressful. Students in such a case lose motivation for work and the level of their performance declines. The function of a ventilation system is to supply fresh air indoors and freshen up the occupants. (Heidorn, 1997). If there is good air movement combined with hot and humid air, this helps the body to lose heat and thus creates thermal comfort. If air is motionless in hot and humid air, occupants feel stuffy and inactive. The situation gets worse if there are pollutants and odor inside the room. Air movement results naturally from human physical activity and the ventilation system. (Heidorn, 1997). A study conducted on students to find out the impact of ventilation on school students aged 10 to 12, it was found out that good ventilation improves performance by 8 to 14%. (Technical University of Denmark, 2009).

2.3 Recommended Types of Indoor Plants.

Not all plants can be grown indoors as some are not good survivors and need a lot of water and light. However, there are a number of plants which are best suited for indoor environment. Among these plants are: (Sustainable Baby Steps n. d.)

1. Aloe Vera. The scientific name of this plant is *Aloe barbadensis*. It is known for absorbing formaldehyde from air. It needs well-drained soil while watering.

Figure 2.2: Aloe Vera (Sustainable Baby Steps n. d.)

2. Areca Palm. The scientific name is *Chrysalidocarpus lutescens*. It is known to be an excellent air purifier by filtering xylene and toluene from the air. It needs well-drained soil.

Figure 2.3: Areca Palm (Sustainable Baby Steps n. d.)

3. Baby Rubber. The scientific name is *Peperomia obtusifolia* or *Ficus robusta*. It is known to be an air purifier by removing formaldehyde and other pollutants. It needs rich soil and lighting.

Figure 2.4: Baby Rubber (Sustainable Baby Steps n. d.)

4. Bamboo Palm or Reed Palm. The scientific name is *Chamaedorea seifrizii*. It is a good air purifier and natural humidifier. It requires lighting and moist soil but not much water.

Figure 2.5: Bamboo Palm or Reed Palm (Sustainable Baby Steps n. d.)

5. Boston Fern . The scientific name is *Nephrolepis exaltata Bostoniensis*. It is known to be one of the best air purifiers. It needs bright light and damp soil but it can tolerate drought.

Figure 2, 6: Boston Fern plant (Sustainable Baby Steps n. d.)

6. Chinese Evergreen. The scientific name is *Aglaonema sp*. It emits high levels of oxygen and removes chemicals like formaldahyde, benzene or other toxins. It needs drained soil and sunlight. The sap of this plant is poisonous.

Figure 2.7: Chinese Evergreen tree (Sustainable Baby Steps n. d.)

7. Corn Cane or Mass Cane. The scientific name is *Dracaena massangeana* or *Dracaena fragrans massangeana*. It is one of the best air purifiers as it removes formaldehyde and other toxins. It grows well with little light and water.

Figure 2.8: Corn Cane or Mass Cane plant (Sustainable Baby Steps n. d.)

8. Dwarf/Pygmy Date Palm. The scientific name is *Phoenix roebelenii.* It removes formaldehyde and xylene from the air. It needs sunlight, moist soil and warm water.

Figure 2.9: Dwarf/Pygmy Date Palm (Sustainable Baby Steps n. d.)

9. English Ivy. The scientific name is *Hedera helix.* It is an excellent air purifier as it can remove benzene and formaldehyde from the air. It has been found to treat asthma, and allergies. It spreads fast to areas within its vicinity.

Figure 2.10: English Ivy (Sustainable Baby Steps n. d.)

10. Ficus alii. The scientific name is *Ficus maeleilandii alii*. It is one of the best air purifiers. It needs indirect sunlight and little water. It can cause allergies to people who are sensitive to latex.

Figure 2.11: Ficus alii (Sustainable Baby Steps n. d.)

11. Gerbera Daisy. The scientific name is *Gerbera sp*. or *Gerbera jamesonii*. It removes benzene which is known to cause cancer, and absorbs CO2 and emits oxygen. It needs bright light.

Figure 2.12: Gerbera Daisy plant (Sustainable Baby Steps n. d.)

12. Golden Pothos. The scientific name is *Epipremnum aureum syn. Scindapsus aureus*. It is one of the best three plants to remove formaldehyde and carbon monoxide from the air. It needs less water in cold temperature and little sunlight.

Figure 2.13: Golden Pothos (Sustainable Baby Steps n. d.)

13. Janet Craig. The scientific name is *Draecana deremensis.* It is an excellent air purifier. It needs watering and indirect sunlight and requires no fertilizers.

Figure 2.14: Janet Craig plant (Sustainable Baby Steps n. d.)

14. Kimberly Queen Fern. The scientific name is *Nephrolepis obliterate.* It is an excellent air purifier as it removes formaldehyde, toluene, and xylene from the air. It needs indirect sunlight with dry soil between watering but not for a long time.

Figure 2.15: Kimberly Queen Fern (Sustainable Baby Steps n. d.)

15. Lady Palm. The scientific name is *Rhapis Excelsa.* It removes most pollutants. It needs little sunlight and frequent watering in the summer (but should not be soaked in water), andshade in the winter.

Figure 2.16: Lady Palm (Sustainable Baby Steps n. d.)

16. Marginata or Dragon tree. Its scientific name is *Dracaena marginata*. It removes benzene, formaldahyde, xylene, and trichloroethylene. It needs little care and tolerates dryness. It needs indirect sunlight but it is susceptible to fluoride toxicity as some water is fluoridated.

Figure 2.17: Marginata or Dragon tree (Sustainable Baby Steps n. d.)

17. Moth Orchid. Its scientific name is *Phalaenopsis.* It removes volatile organic compounds) and formaldehyde. It needs humidity, lenty of sunlight (but not midday summer light) and enough water with some periods of dry soil.

Figure 2.18: Moth Orchid plant (Sustainable Baby Steps n. d.)

18. Mums. Its scientific name is *Chrysanthemum sp.* or *Chrysanthemum morifolium.* It removes benzene, trichloroethylene, formaldehyde and ammonia. It requires partial sunlight and plenty of water. They bloom once a year.

Figure 2.19: Mums or Chrysanthemum morifolium plant (Sustainable Baby Steps n. d.)

19. Peace Lily. Its scientific name is *Spathiphyllum sp.* It removes alcohols, acetone, formaldehyde, benzene and trichloroethylene. It needs plenty of water and bright indirect sunlight.

Figure 2.20: Peace Lily (Sustainable Baby Steps n. d.)

20. Philodendron. Its scientific name is *P. cordatum*, *P.scandens* or *P. selloum*. It removes formaldehyde. It is a poisonous plant so it should be kept out of children's reach.

Figure 2.21: Philodendron plant (Sustainable Baby Steps n. d.)

21. Snake Plant. Its scientific name is *Sansevieria trifasciata.* It removes toxins like nitrogen oxides and formaldehyde. It requires little sunlight and watering.

Figure 2.22: Snake Plant (Sustainable Baby Steps n. d.)

22. Schefflera, or Umbrella Tree. Its scientific name is *Brassaia actinophylla.* It removes benzene. It requires indirect sunlight and plenty of water and humidity.

Figure 2.23: Schefflera, or Umbrella Tree (Sustainable Baby Steps n. d.)

23. Spider Plant. Its scientific name is *Chlorophytum comosum*. It removes formaldehyde, monoxide and other pollutants. It needs bright but indirect sunlight and plenty of water.

Figure 2.24: Spider Plant (Sustainable Baby Steps n. d.)

24. Warneckii or Dracanaena warneckei. Its scientific name is *Dracaena deremeusis* or *Dracanea deremensis warneckei*. It needs moderate sunlight and water but no soaking or fluoridated water.

Figure 2.25: Warneckii or Dracanaena warneckei plant (Sustainable Baby Steps n. d.)

25. Weeping Fig or Ficus Tree. Its scientific name is *Ficus benjamina.* It removes toxins from air and produces oxygen. It needs bright sunlight but it tolerates shade. It also needs moderate watering.

Figure 2.26: Weeping Fig or Ficus Tree (Sustainable Baby Steps n. d.)

After listing the best suited indoor plants for interior environments it can be concluded:

Indoor plants can survive in UAE indoor environments because of buildings controlled indoor atmosphere, the harsh weather in UAE during the six months of summer which the levels of temperatures reach 45 C^{O} in a day cause uncomfortable indoor environments in buildings. That explains the dependence of UAE buildings on (A/C) as ventilation system.

Using A/C as ventilation system in a building manages temperature and humidity levels in a space which gives better controlled indoor environments for interior plants. Most indoor plants needs controlled indoor environments proper light and normal temperature levels with little water.

The selection of indoor plants in a space depends on several points:

1. Plant ability as air purifier and air pollutants removers, the more ability of cleaning air the more efficient a plant will be.

2. A plant's ability to adapt to intermediate temperatures and humidity with average light levels.
3. Size of plant and leafs amount and width. Size of plan must remain small not to extend out from the green-wall, while plant leafs should be wide to maximize plant ability of cleaning air.
4. The birthplace of plant and which country is coming from, by that it can be decided if the plant can survive in other kind environments.
5. Avoid poisonous plants.
6. Avoid plant cause allergies to people.

2.4 Previous Studies.

Doxey, Waliczek and Zajicek (2009) conducted a study on 385 students to test the impact of classroom plants on their performance. It followed an experimental approach in which the students at the same course taught by one professor were tested to see if the existence of plants in one of the classrooms made any difference in the students' performance. Comparing the results of examinations, it was found that there was no statistically significant difference between the treatment group and the control group in terms of academic performance. However, there were statistically significant differences between the two groups in terms of enthusiasm, organization and mood.

In a study conducted by Lee and Guerin (2009) on LEED certified buildings, the correlation between the criteria of LEED Internal Environment Quality and occupants' satisfaction and performance were established, a questionnaire was designed and distributed to 3769 office workers from 15 buildings. The questionnaire comprised of questions measuring seven criteria: quality of office layout, furnishings, thermal comfort, indoor air quality, lighting, acoustics, cleaning and maintenance. The response ranged from “very satisfied” to “very dissatisfied” according to the Likert scale. Pearson correlation coefficient was used to find out the relation between the variables, and it was found out that there was a significant positive relationship with occupants’ satisfaction with overall conditions of workspace.

Another study was conducted by Paul and Tylor (2008) titled “A comparison of occupant comfort and satisfaction between a green building and a conventional building.” The study compared two kinds of buildings: green and conventional located in Albury-Wodonga, in inland southeast Australia in terms of their effect on productivity. The green building was naturally ventilated and constructed from rammed earth and recycled material whereas the conventional building was artificially ventilated and air-conditioned and constructed from brick veneer. A questionnaire was designed for the purpose to measure comfort in terms of aesthetics, serenity, lighting, acoustics, ventilation, temperature, humidity, and overall satisfaction. The study sheds doubts on the claim that green buildings affect productivity positively. It concluded that there is no significant relation between green buildings and productivity.

In another study conducted in Italy and the UK to assess the effect of green spaces on people by Lafortezzaa et. al.(2009), the physical and psychological dimensions were assessed as perceived by the respondents. The study was entitled “Benefits and well-being perceived by people visiting green spaces in periods of heat stress.” The study discovered that frequent visits to green spaces during heat episodes alleviate stress and discomfort caused by heat.

Another study entitled “Benefits of indoor plants on attention capacity in an office setting” by Raanaas, R. (2011) was conducted to find out the effect of foliage and greenery on students in an office setting. There were 34 students and the tests took place in an office. In the first test, the office was provided with four plants and in the second instance, the plants were removed. The test took the form of a reading span test conducted thrice. It concluded that performance in the office with plants was better than in the office without plants.

Eumorfopoulou and Kontoleon (2009) conducted a study entitled “Experimental approach to the contribution of plant-covered walls to the thermal behavior of building envelopes.” The study was conducted on the surface of the walls and not on people. It aimed to find out the dynamics of thermal characteristics of wall envelopes. It concluded that covering walls with plants can improve the thermal characteristics of surface envelopes, and that it had a cooling effect by reducing temperatures by 1-2 C°.

Frontczak and Wargocki (2011) surveyed the literature related to the effect of indoor environment on its occupants. The focus of this study was indoor environment comprising thermal, visual and acoustic, as well as air quality. The writers aimed at defining what previous research has discovered regarding these elements. They state that thermal comfort ranked as the most important factor of internal environment compared with acoustic, visual and air quality. Thermal comfort was found to influence overall satisfaction with the internal environment greater than other elements.

A study was conducted by Daly, Burchett and Torpy (2010) to assess the effect of classroom plants on students’ performance. The study followed an experimental approach on 360 students in 13 classes. The students were pre-tested before placing plants in the classrooms and after that as well. The tests were on mathematics, spelling, science and reading. It was found that the students' performance improved after putting the plants in two schools, and there was no difference in the third school. The researchers attributed the no-difference finding to the fact that the school already had a gardening program and the students were already used to natural greening, and therefore, they were not affected by the plants indoors. The researchers concluded that it is time that schools introduce classroom plants as a result of the numerous studies confirming the positive impact of plants on students' performance.

Dijkstra a, Pieterse and Pruyn (2008) conducted a study aiming to find out the effect of natural plants in a hospital room. The experiment was conducted in the Netherlands. The participants were 77 persons. They were shown two pictures of hospital rooms: one with plants and the other without plants, but with a painting of landscape on the wall. They were told that the patients were diagnosed with legionella. Then they were asked to describe the feelings of the patients. It was found out that the participants who saw the rooms with plants reported that the patients had less stress than the patients in the room with a picture only. The researchers concluded that there is a general belief that plants reduce the level of stress.

The nine studies reviewed above are similar to the current study in that they all deal with the same topic and follow the same methodology. Doxey, Waliczek and Zajicek (2009), Daly, Burchett and Torpy (2010) and Raanaas, R. (2011) tested the impact of plants on students' performance by testing them before placing the plants and again after that. The first study confirmed that there was no difference in the students' performance in relation to the variable of plants while the other two confirmed that there was a relation between the presence of the plants and students' performance.

Skov (1990) conducted a study on the effects of indoor foliage plants and full spectrum, fluorescent light on health and discomfort symptoms among pupils in a junior high school. Revealing problems with the indoor air quality in the classrooms were the circumstances for authenticating this study in a junior high school 15 km (9.3 miles) southwest of Oslo, Norway. In February 1997, tropical indoor plants were planted in three classrooms in a bioprocess system (indoor air flows through the soil/ root-zone) The following plants were used: golden evergreen, striped dragonpalm, corn plant, golden pothos, heartleaf philodendron,and javan grape. The total symptoms or health complaints were 21% lower among pupils in biological classrooms compared to those in the classrooms without the indoor plants. Complaints including headaches and dry or hoarse throat were found to be 37% and 36% lower, respectively. Minimal differences between pupils in the three types of classrooms were observed regarding symptoms of flu or colds: both groups of pupils seemed to be affected at the same spectrum. In spite of this, complaints regarding respiratory symptoms (dry, itching eyes and dry or hoarse throat) and headache were indicatively lower in the biological classrooms, denoting less strain created by the indoor environment. This is due to the fact of that the content of air contaminants are decreased, and there is no doubt that indoor plants is a key attribute to improve the indoor environment in such a way that it positively affects productivity, work satisfaction, or even sick-leave absence.

R. J. Shaughnessy conducted a study on unsatisfactory conditions leading to substandard indoor air quality (IAQ) in classrooms have been regularly mentioned in research over the past two decades. Poor IAQ resulted in frequent absenteeism and learning capabilities, and subsequent poor student achievements, supporting this theory which presents a challenge in today's school environment. This study investigated the relationship between student performances on standardized aptitude tests that are conducted to students on a yearly basis, to classroom carbon dioxide (CO_2) concentrations, which provided a surrogate of ventilation being provided to each room. The data collected on a classroom with CO_2 concentrations, over a 4–5 h time span on a typical school day were recorded in fifth grade classrooms in 54 elementary schools yielded a significant result of ($P < 0.10$) relationship between classroom- level ventilation rate and test results in math.

GA Heath and MJ Mendell also conducted a study "DO INDOOR ENVIRONMENTS IN SCHOOLS INFLUENCE STUDENT PERFORMANCE" The objective of their research was to critically assess available evidence on relationships between indoor environmental quality (IEQ) in schools and student performance. As the available evidence from schools was limited, the research expanded to include studies on direct relationships between the performance of children and adults and the indoor environments in schools, workplaces, residences, and controlled laboratory settings. The most compelling accessible evidence suggested that some aspects of IEQ such as low ventilation rate and less daylight or light, decreased the performance of students in schools. Other evidence identifies additional possible influences, such as pollen and some carpets.

Associations between classroom CO_2 concentrations and student attendance, this study were conducted by Shendell et.al (2004). This study explored the association of students' absences with measures of indoor minus outdoor carbon dioxide concentration. Absence and CO_2 concentration data were collected from 409 traditional and 25 portable classrooms from 22 schools located in six school districts in the states of Washington and Idaho. Study classrooms had individual heating, ventilation, and air conditioning systems, except two classrooms without mechanical ventilation. Forty-five percent of classrooms studied had short-term indoor CO_2

concentrations. This study does provide motivation and a platform for larger research to investigate the linkage of longer term CO_2 concentration data and more accurately measured ventilation rates with student absence.

A study titled “Use of living pot-plants to cleanse indoor air” was conducted by Jane Tarran, Fraser Torpy and Margaret Burchett. Urban indoor air quality (IAQ) is a global health issue, since city dwellers spend 90% of their time indoors. A range of investigation and studies affirm that indoor plants do improve IAQ and supports the occupant wellbeing.

This study included nine indoor plant species and it was recorded that these potted plants reliably decreased volatile organic compounds which is a significant kind of indoor pollutants and contaminants by 75%. They work equally in conditions such as, with or without air-conditioning, and in light or dark. Studies have also presented the fact that these potted-plants can also remove indoor CO and, sometimes CO_2. The evidence clearly demonstrated that the potted-plant microcosm (a world) represented an inventive technology for dealing with indoor air pollution, which can result in a range of harmful health effects that can lead to other related illnesses. This manageable, adaptable, attractive, inexpensive technology can accompany any engineering actions and can be used in any building

During the last 20 years, researchers have explored the relationship between IAQ, health and productivity. Clearly, indoor plants can affect indoor environments, human performance and productivity somehow, despite other factors in the physical environment also influence productivity, including acoustic comfort, cleanliness and ergonomics, but they will not be part of this discussion.

Chapter 3: Research Methodology

3.1 Ethical Consent and Experiment Procedures

The experiment was done in one of the classrooms at Ajman University of Science and Technology (Ajman- UAE) during the first semester, September 2013 until January 2014, after taking permission and acceptance from the university's official authority and students themselves. This was done in order to place the green-wall system in two classrooms (each used male and female students) and then had them fill out surveys to analyze their scores and comments. Finally, indoor air quality and thermal comfort levels were measured during class sessions.

Male and female students with ages ranging between 19 to 30 years old participated in this experiment; the majority were from Arab Middle Eastern countries (Syrians, Jordanians, Palestinians, Egyptians), some were South Asians (Indians, Pakistani), and there were a few from the Gulf countries (Emirates, Saudi, Kuwaiti). The students were all majoring in Interior design in the fourth year because their lectures' time duration were long, and the number of students in each section was varying between 10 to 14 members. They were learning a design course in the class. The Lecture was 4 hours long and started from 8:30 am till 1:30 pm.

Fifty students were participating in the survey before and after installing the green-wall, while ninety nine students in total were selected to compare their marks with the control classroom that contains the green-wall.

The researcher employed a Qualitative and Quantitative approach as follows:

1. The Qualitative approach used a questionnaire as a tool to find out the level of comfort that the students felt.
2. The Quantitative approach involved measuring air components before and after placing the green wall.
3. Obtaining students' scores from their teacher for the class with a green-wall and for the classes without a green-wall.

The questionnaire was done in the experimental class before and after placing the green wall in two phases; the first was from 10th of September till the 19th of October without the green-wall in the classroom, and the second was from 18th Dec. 2013 till 25th Dec.2013 where the green-wall was placed.

During this period a survey was conducted among the students and instructor to evaluate student's levels of comfort before and after locating the green-wall.

The questions of the survey consist of three sections: Section (A) consists of six questions aimed at assessing student's level of comfort based on constant acceptability measure scale which varied from (1) Very dissatisfactory, (2) Dissatisfactory, (3) Neutral, (4) Satisfactory and (5) Very satisfactory.

Section (B) of the questionnaire consisted of nine questions related to the effect of indoor environment on the students, choices of the questions dealt with issues related to measures they take in order to feel more comfortable such as: adding or removing a layer of clothing, switching on or off the air conditioning system and opening the windows. Other questions dealt with problems and symptoms that the students could experience during the lecture such as: allergy, migraine, dry eyes and unusual downing , fatigue or tiredness. Moreover, questions dealt with the classroom’s acoustical comfort and safety.

Section (C) was related to the instructors’ opinions on student’s performance, participations and productivity.

As mentioned before, IAQ and Thermal Comfort levels were measured in this period by using (TIQ-610) probe shown in Figure3.1, used for measuring the following: TVOCs / Carbon Dioxide / Carbon Monoxide / Ozone / Indoor air temperature / Relative Humidity. Figure 3.2 illustrate the Acoustical Levels device which called (Sound Level Alert tool). PMs Levels were measured using another tool called (Thermo Scientific) as in Figure 3.2. These portable devices are highly accurate and can measure different indoor pollutants.

Figure 3.1: IQ-610 probe and PCC_10 Security Case with IQ-610 probe (Wolf Sense, 2009)

Figure 3.2: Thermo Scientific pDR-1500 (Thermo Scientific, 2011)

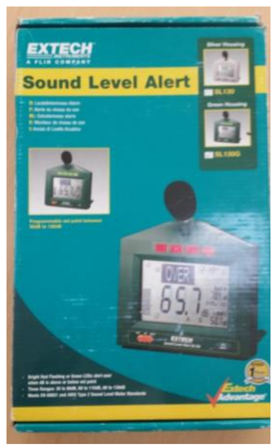

Figure 3.3: Sound Level Alert used in the experiments.

The devices were used in Experiment One and in Experiment Two. In experiment one the measurements were taken in the same time (morning) through the five days. Tools were placed in the middle of the classroom during the lecture for half an hour; measurements were taken twice (when the A/C was on and off) because A/C systems will affect the actual quality of the classroom's indoor air by importing new air from other spaces, thereby enabling accurate assessment of the extent to which the green-wall improved indoor air quality.

In experiment two the tools were located in two positions once near the green-wall and then further away for another five days, and the A/C was turned off while taking the measurements.

The second quantitative test was followed by obtaining the scores record from the teachers for the experimental class students and three other classes in the course of Engineering Graphics. All the students were seniors and majoring in Interior Design. The total number was 99 students, of which 20 were in the experimental class whereas 79 students were in the control classes. The scores were taken from the instructors for the four classes in their 1st, 2nd, and final examinations.

The following Table shows the scenario followed for the experiment from 10th of Sep.13 till 6th of Jan 14.

Table 3.1: Students numbers and the followed steps of the experiment

Step	Date	The followed steps	Number of Students response
1.	10th Sep. 2013 till 19th Oct.2013	○ Experiment One A. Survey done before installing Green-wall B. Measuring IAQ & Thermal comfort levels	50 Total 19 male-31 female
2.	19th Oct.2013	Green-wall Installed	
3.	18th Dec. 2013 till 25th Dec.2013	A. Survey done after installing green-wall B. Measuring IAQ & Thermal comfort levels	37 Total 10males-27 females
4.	6th Jan.2014	○ Experiment Two Measuring IAQ & Thermal Comfort levels near and far the green-wall at the same time.	
5.	10th Jan.2014	Comparing & Analysing students marks	99 Total 20 in the experimental class 79 in the control class

3.2 Test Technical Information

The experiment was conducted in Ajman University of Science and Technology at the college of engineering at the Interior Design classrooms. The experiment's duration was for five days. There were two classrooms; one for males and one for females, but the two classes have the same space dimensions and design. The classroom was chosen according to its size (smaller was preferable), the room volume was around 54 m^3 (Width 6m, length 7.75m,height 3.75m,) with a large window located at the back of the classroom. Central A/C was used for ventilation and cooling, no windows were allowed to be opened. The Experiment was conducted in the same class but for four groups. Figure 3.1 shows the classrooms plan with the location of the green-wall.

Figure 3.1: Plan of the Classroom with location of green-wall

Figure3.2: Figure 3.2: Female classroom with green-wall.

Figure 3.3: Males classroom with green-wall.

The green wall system was chosen after thorough searching, and the selected one was simple, easy to fix, and with simple water circulation. Its size was 80cm width X 200cm high, holding 27 plants with 15 cm diameter size for each plant Figure 3.4.

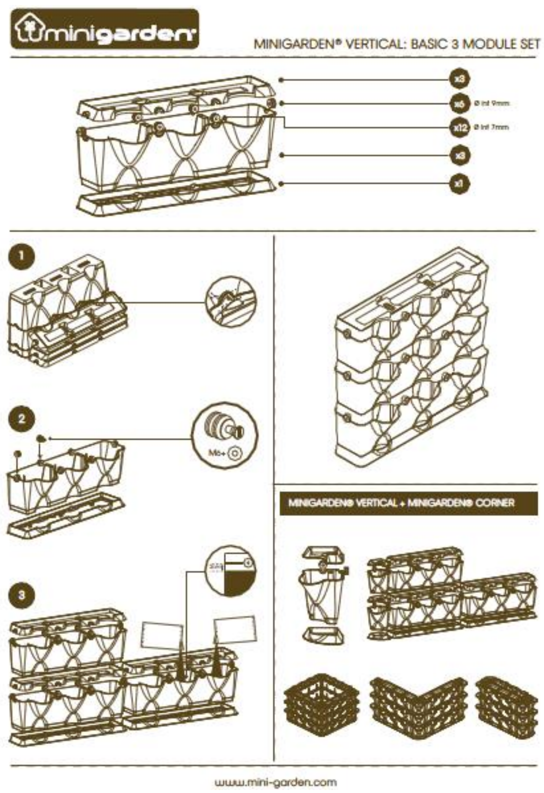

Figure 3.4: Green-wall system used in the experiment and located in the classroom.

Mini garden vertical model set of green-wall system was selected because of its reasonable price and its easy wall fix. This system can hold much more plants than other systems, also plants can be watered from the openings located at the front where extra water can filter down reaching the end of the set (Figure 3.4).

The size of the green-wall was determined according to the maximum space available in the front wall of the classroom. There was a space of one meter available near the white board; this space was filled with plant set of 80 cm width each set contained three plants. Nine sets were attached to the wall vertically with a height of two meters. Number of plants that the whole set could hold was 27 in each classroom. It is noted that it is possible to increase the size of the green-wall, but financial issues limited this to happen.

Figure 3.5: Types of plants were chosen in the green-wall, Peace lily, Dracaena Fragrans, Croton prospectively.

These types of plants were chosen based on:

- Their ability to adapt under indoor conditions such as A/C and artificial light; furthermore these plants are considered to be air purifiers as well as can be used in closed spaces.

-Plants with large leaves were preferred, larger plant leaf surface area means higher transpiration rate and greater surface area to absorb airborne chemicals. (Wolverton Environmental, 2013)

- The size of the three different plants will not extend out from the green wall. There are limit for these plants growth that keep the plants small.

-Three kinds of plants were used to serve out design requirements, to give a good view while looking at the green-wall. Peace lily plant were use because of its elegant appearance with small white flowers that give a good view and nice smell, while Dracaena Fragrans and Croton plants have different leaf shapes that give different design to the green-wall.

3.3 Data Analysis Method

The results that were obtained from the measuring tools in the first experiment and second experiment which are TVOCs, Carbon Dioxide, Ozone, Carbone monoxide, Total particulate matter, Temperature, Humidity and acoustical levels were analysed as follows: Female classroom before and after green-wall with A/C and without A/C, and Male classroom before and after green-wall with A/C and without A/C. To compare and assess the results significant deference was calculated for each parameter to find the changes that took place to the air quality. Mann-Whitney test was used to assess these parameters statistically and Mini-tap software was used to get the graphs.

Significant difference or the *p-value* is a key concept used to measure the probability of obtaining a test statistic result. If results were ranging between 0.05 and 0.01 that means there is a strong presumption against neutral hypothesis, and if the results were above 0.05, results will be ignored.

There was a survey done before green-wall and after green-wall. The questionnaire was evaluated by taking the mean average of each question and comparing answers before and after locating the green-wall. The results were ranging between (1) Very dissatisfactory (2) Dissatisfactory (3) Neutral (4) Satisfactory (5) Very satisfactory.

Scores were analysed by taking the total mark for each student and the average score for the whole class in percentage for the four classes, then a comparison will be done to the average to see any significant differences.

3.4 Limitations of the Study

Different limitations were needed to be addressed to achieve advanced results. Study limitations must be addressed in order to evaluate this study and enhance future investigation.

1. Devices readings accuracy was one of the limitations that could affect research outcomes, the efficiency of the device could be changed by time according to device age. Its surface could collect some dust and contamination that lowers its sensitivity.
2. Honesty of people, dealing with students most of them in the young age bracket could affect the answers' accuracy.They may want to impress the researcher and fabricate the truth, or they are in a hurry so they could answer quickly.
3. Funding was one of the disadvantages in this research that did affect its results. The researcher was the only funder for this research, and that was reflected in green-wall size. If the research budget was larger it could affect the design and size of the green-wall, thus its effect on indoor air would be greater.
4. Controlling the surround environment while taking measurements was difficult. The researcher experienced some activities that affected the accuracy of data, such as the existence of a workshop class in the same area of the experiment classroom, which was affecting the quality of the measurements. So because of these limitations the researcher did another experiment to get better results by changing the method of taking measurements which will be near and far green-wall in the same time in the classroom.
5. Professors were not cooperative and didn't respond to survey questionnaires which has an effect on research progress that can be presented in section (C) of the survey which only one lecturer replied to.

Chapter 4: Analysis and Discussion of Results.

4.1 The Effect of Green-wall on Classroom IAQ and Thermal Comfort.

4.1.1 Experiment One.

Experiment One assessed IAQ and Thermal Comfort levels in the two classrooms; for females and males, and two main scenarios with two different conditions were applied. The two scenarios measured the TVOCs, Carbon Dioxide, Temperatures, Ozone, Humidity, Carbon Monoxide, Total Particulate Matter and Acoustical levels in the female classroom throughout five days, with the green-wall, and two different conditions were further applied, once with the A/C on and again without the A/C. The second scenario consisted measuring the classrooms without the green-wall, and again with the same two conditions; the A/C on and off. The devices were located in the middle of the classrooms, where students were found in the rooms and lectures were conducted. In this discussion, the focus and comparison will be on the TVOCs, Co2 and Temperature levels only because it was noted that these three elements were most affected by the experiment and the application of the green wall, and major differences were observed during the data collection sessions.

The number of students inside the classroom ranged from 10 to 13 during the data collection, and measurements were taken in the morning at 9:00 am every day throughout five consecutive days.

Figure 4.1. shows the measurement regarding Total Volatile Organic Components (TVOCs) in five days for females and males. It is evident that there is no regular pattern for the results that points to a cause for the different readings. That is reflected when comparing the two scenarios for TVOCs when there is green-wall with A/C and no A/C and no green-wall with A/C and no

A/C throughout the five days. The first scenario (with green-wall) for the female classroom didn’t show any reasonable changes in the levels of TVOCs, and there was no significant difference observed statistically ($P>0.05$) when comparing it with the second scenario (without green wall).However there were a significant difference in the male classroom ($P=0.05$) which means there was a slight decrease in the pattern of TVOCs when green wall existed and A/C was on during the five days.

Furthermore, it can be noted that during the scenarios where the A/C was switched on and the green-wall was found in the room, the TVOCs levels was reduced on average of the five days compared when the A/C was switched off. The same was also observed when measurements were taken without the green wall and the A/C was switched on. This is due to the air movement that is initiated by the A/C as it carries air that moves across the building and in-between rooms, carrying particles found in one location and forwarding it to another place. This is why the TVOCs levels increased in both green-wall scenarios when the A/C was on, as outside particles were brought into the classrooms with the air movement.

Moreover, a workshop was taking place on the same floor doing wood saw work. This would increase the smells in the air and the insides of the classrooms. So, the big difference noticed in the second day can never be attributed to the green-wall; otherwise, the subsequent reading should also show a similar difference. It can be deduced that the workshop was not working at the time of measurement on the second day and that is why the level of TVOC was much lower on the second day. The same thing applies to day 5 when the measurement before placing the green-wall was much lower than after placing it. The slight significant difference in the male classroom due to the location of the workshop which was near the female classroom and further away from the male classroom meant that its effect on the TVOCs was fewer. In other words, these measurements do not reflect reality and the impact of the green-wall and the impact of the workshop should not be ruled out.

Figure 4.2. for males and females indicate that there are no significant differences in TVOCs concentration and this is due to the fact that the ratio of the area of the green-wall to the size of the room was not enough to make a difference as it was 166 m3: 1.6 m2 .That means this area of the green-wall has to be at least tripled in order to create a difference.

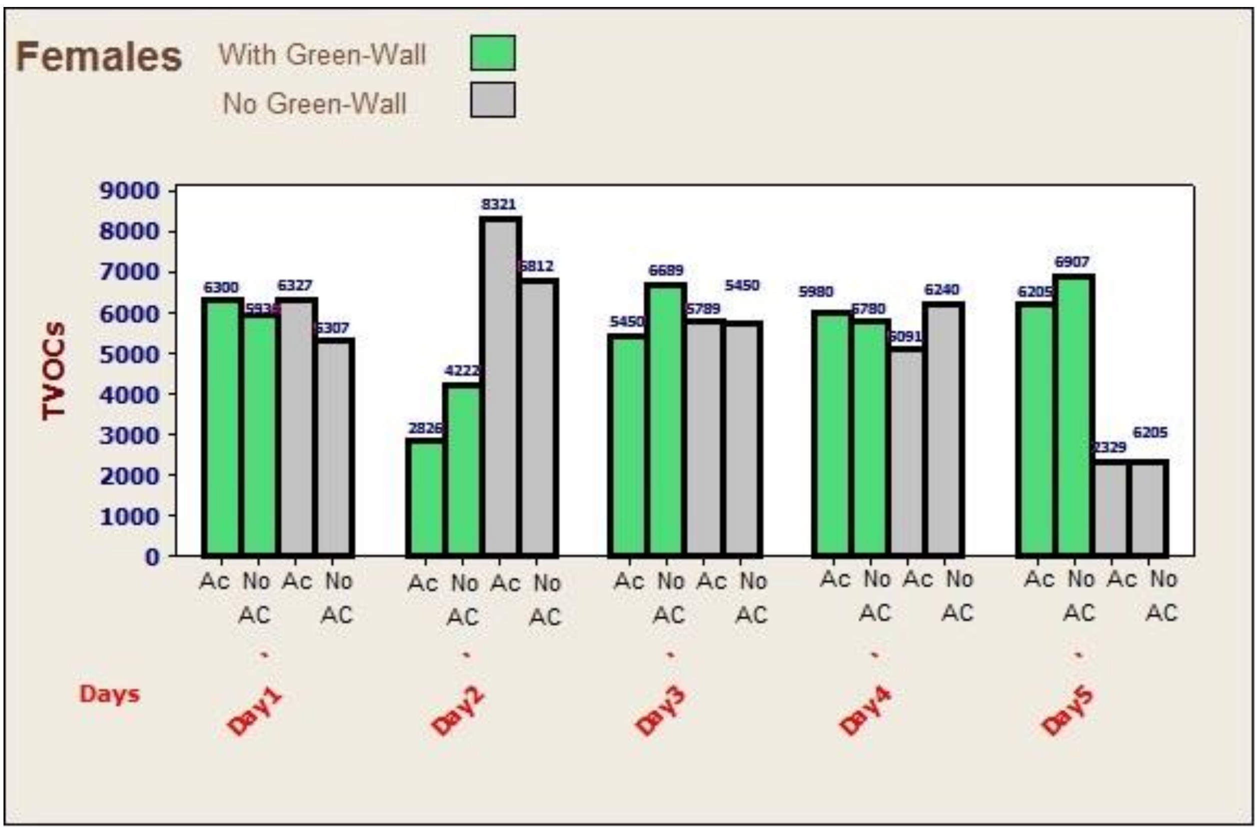

Figure 4.1. : The two scenarios of TVOCs levels in Females classroom through five days, (green-wall with A/C and no A/C) and (no green-wall with A/C and no A/C).

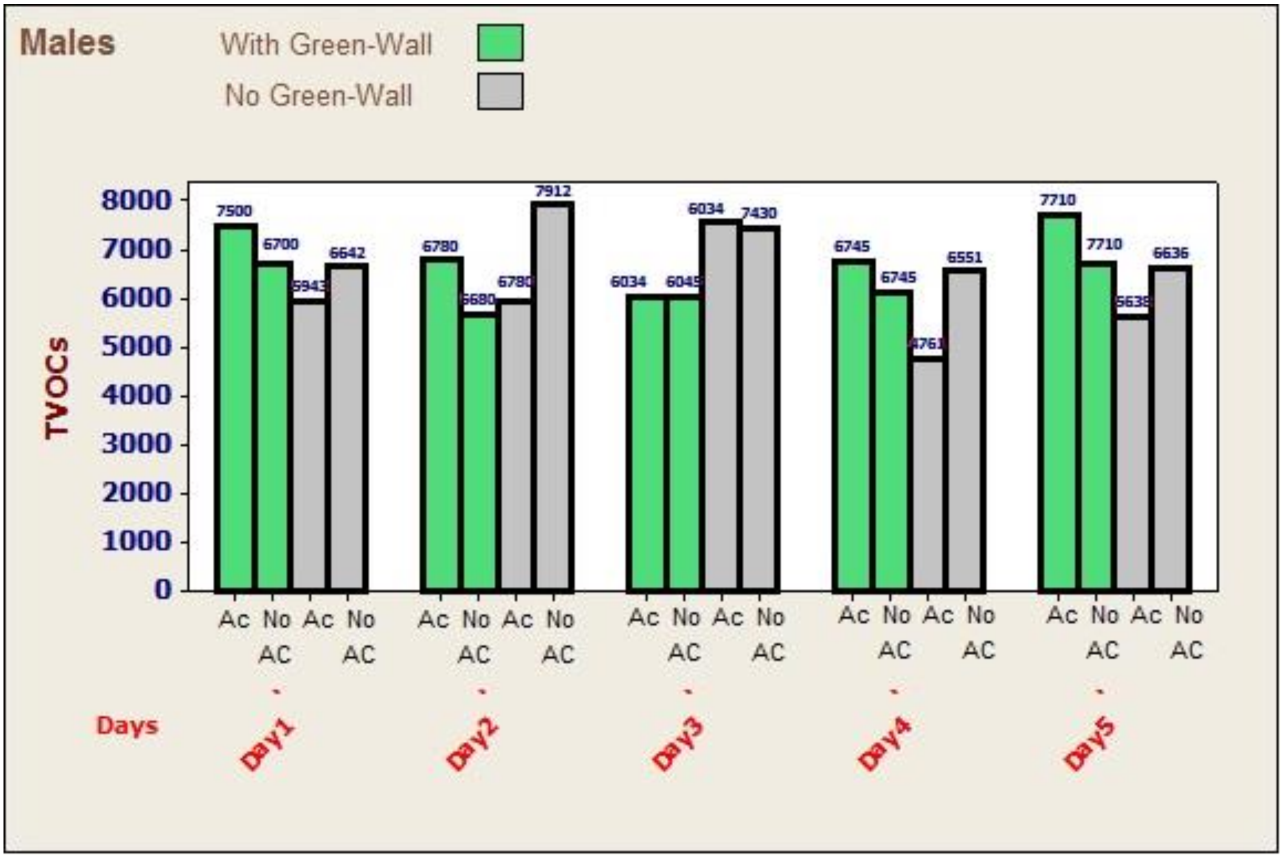

Figure 4.2 : The two scenarios of TVOCs levels in male's classroom through five days, (green-wall with A/C and no A/C) and (no green-wall with A/C and no A/C).

The green-wall was placed to the left of the white board occupying a very small area compared to the overall size. That shows in Figure 3.2 and 3.3 in chapter three, so that its effect remained restricted to the close surrounding air to it. The following Graphs show TVOCS, Carbon Dioxide and Temperature levels when measured were done at the middle of the class in Experiment One.

Figure 4.3 shows the measurement regarding Carbon Dioxide (CO2) concentrations in five days for the female and male classrooms. Again, the same fluctuation appears evident regarding CO2. The measurements increased and decreased without a clear pattern and for no definite reason which rules out any impact for the green-wall. That is shown when comparing the two scenarios for CO_2 when there is green-wall with A/C and no A/C and no green-wall with A/C and no A/C throughout the five days. The first scenario (with green-wall) for the female classroom didn’t show any reasonable changes in the levels of CO_2, there was no significant difference observed statistically ($P>0.05$) when comparing it with the second scenario (without green wall), that was observed in the male classroom too. It seems that the impact of the green-wall was contrary to the assumption of improving air quality.

The high levels of CO_2 in the classroom was affected mainly by the number of occupancy and the rate of ventilation.CO_2 concentration levels should be not more than 1000 ppm (Daisey et al 2003) so the high levels of CO_2 in the two scenarios indicate that the ventilation system in the room cannot sufficiently remove the level of body odour, because windows were not allowed to be opened by the students. This also confirms the fact that the ratio of the plants to the total area of the classroom was not enough to create a difference and the difference was registered only when the measurement was taken too close to the plants in experiment Two.

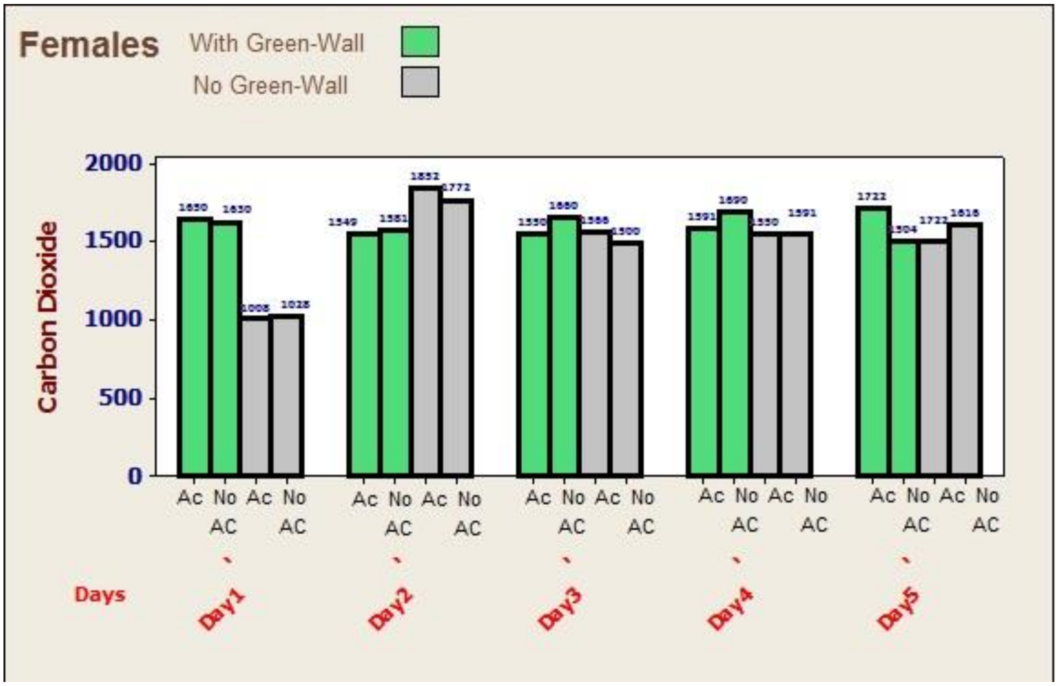

Figure 4.3: The two scenarios of Carbon Dioxide levels in Females classroom through five days, (green-wall with A/C) and (no green-wall without A/C)

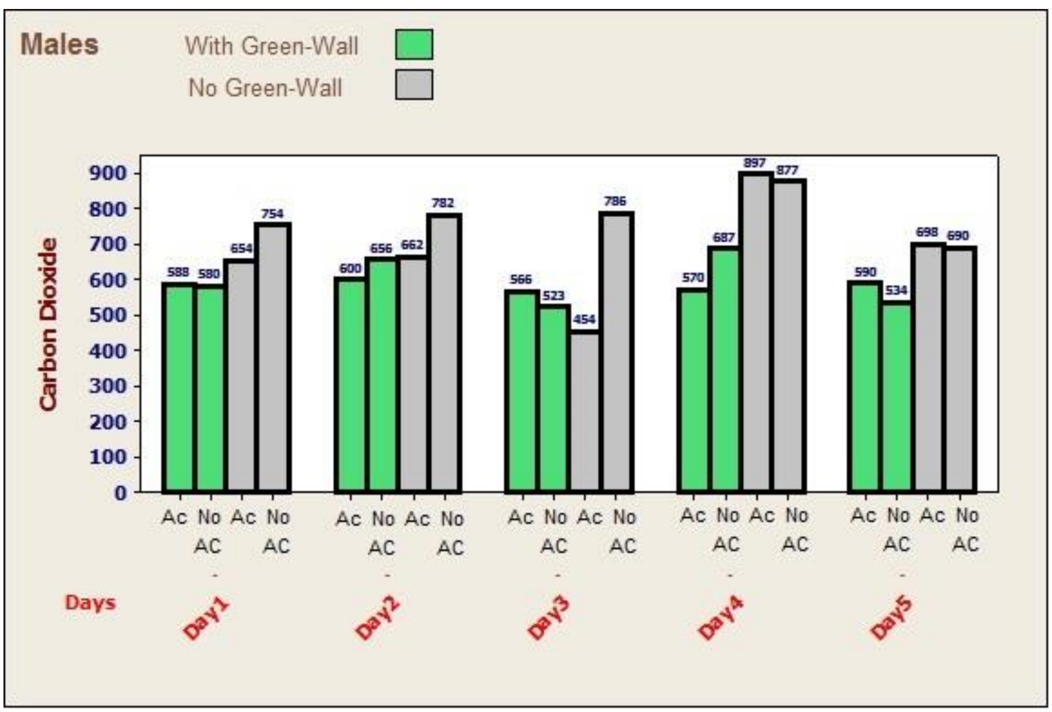

Figure 4.4: The two scenarios of Carbon Dioxide levels in Females classroom through five days, (green-wall with A/C) and (no green-wall without A/C)

The case with temperature is different because the A/C makes a big difference in temperature levels. (See Figure 4.5 and Figure 4.6 for details). Statistical measurements show lower levels of temperature in the female classroom with a significant deference of .04 when comparing the levels of temperature when there was a green-wall with no A/C and no green-wall with no A/C and another significant difference of .05 between the scenarios of green-wall with A/C and green-wall without A/C. In the male classroom there was no significant difference recorded in any condition.

UAE outdoor weather comprises of two seasons. The Summer season has high levels of temperature and humidity for a duration of six months in the year which is from April till September where temperature levels ranges between 40°C to 48 °C , while winter starts from October till March where temperature levels reach no less than 6 °C. (UAE MOEW, 2010) Experiment One was done during winter from September 2013 till January 2014, and that will reflect on students' clothing, as most of the students were wearing heavy clothing inside the classroom which gives them warm feeling that protecting them from the cold weather inside the classroom. Clothing works as an insulation material that surrounds the body which will slow heat loss and heat up the body (Summit Post, 2013).

The average temperature level when the green wall was placed and the AC was switched off measured to be 23.7C, which is within the comfort zone of human beings. It can be deduced that that there was a slight increase in the temperature given that the measurements where taken during the winter climate when generally the room temperatures drop to create a cold uncomfortable condition. Thereby, the green wall helped in providing a warmer, more comfortable room temperature.

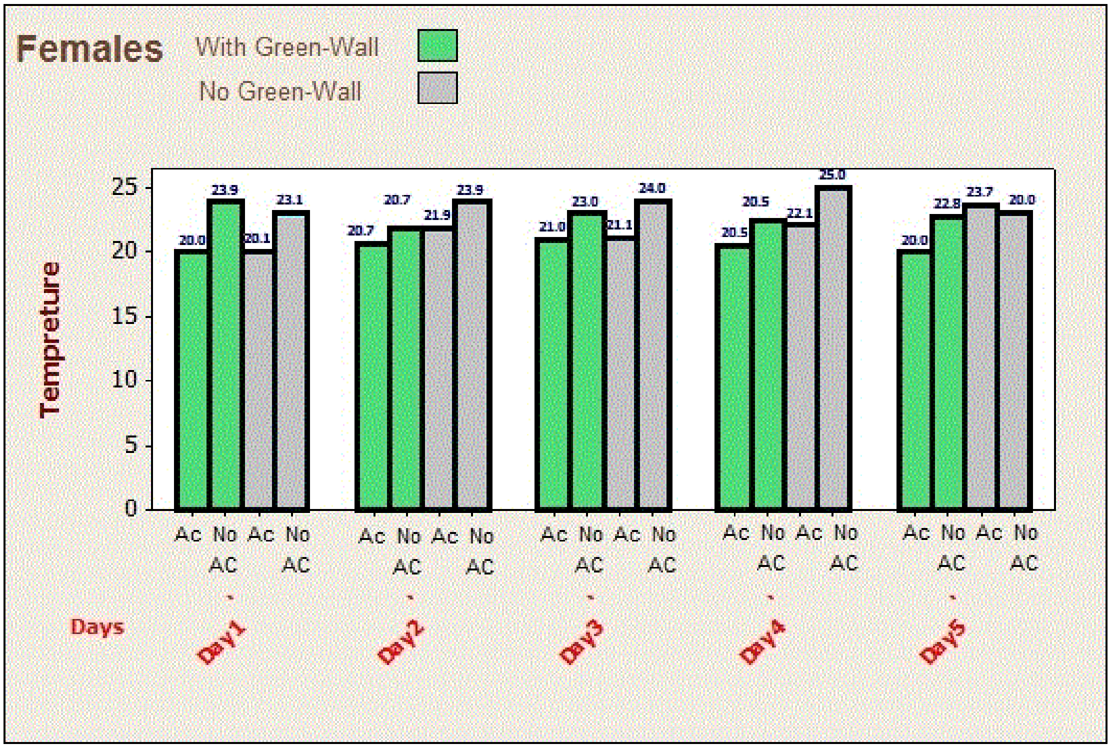

Figure 4.5: The two scenarios of Temperature levels in Females classroom through five days, (green-wall with A/C) and (no green-wall without A/C).

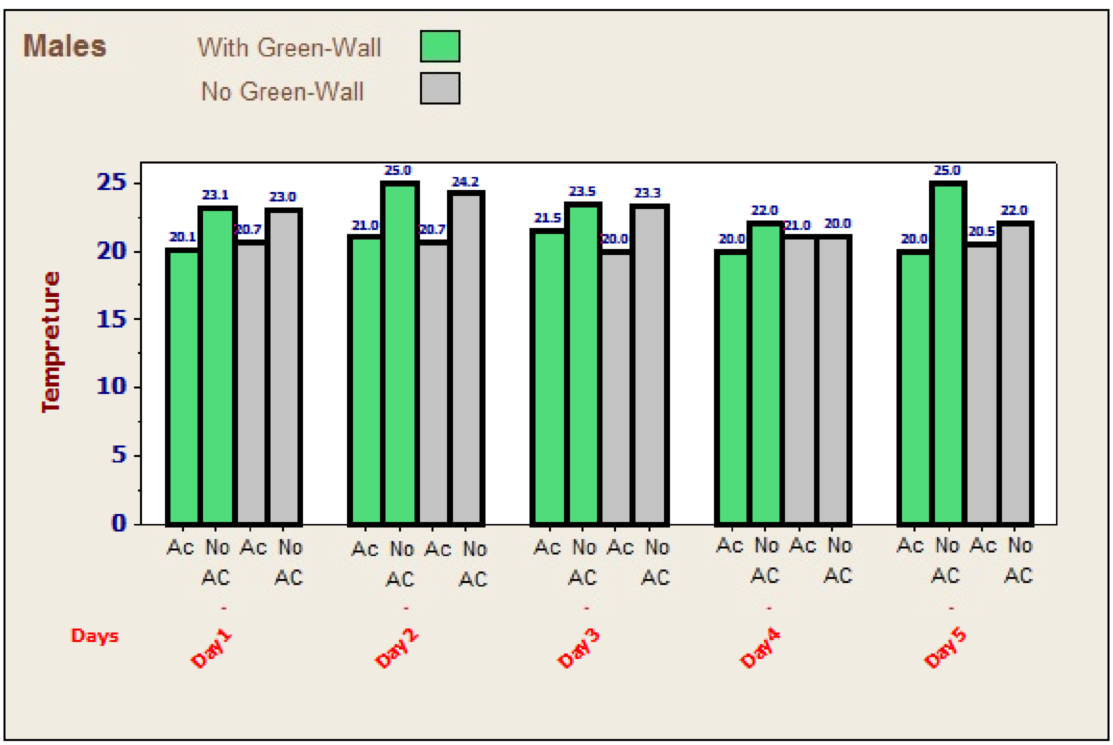

Figure 4.6: The two scenarios of Temperature levels in Males classroom through five days, (green-wall with A/C) and (no green-wall without A/C).

Furthermore plant leaves' transpiration affect the surrounding air and enhances the cooling of the space, when the water from leaf surfaces is evaporate. It use the excess heat from the surrounding air to evaporate, therefore temperature levels cool down (Wolverton Environmental,2014).

Acoustical levels were affected before and after placing the green-wall (measurements shown in Appendix (B). In the female and male classrooms the average acoustical levels before locating the green-wall reached around 78.5, while the average acoustical levels after placing the green-wall reached 70.7. The lower levels of acoustical measurements after placing the green-wall can be explained by the following: The green-wall worked as an acoustical buffer that lowered the number of echoes that were produced in the classroom which reduces the sensitivity of noise for the students. (Kotzen, 2004)

Comparing the results before and after the green wall, the following points can be concluded:
The results of that were not clear, so experiment was failed for several reasons:

A. The levels of VOCs were high because there was a workshop class that was located on the same floor, which affected the quality of the air.
B. Green wall plants were not enough to affect the surrounding air.
C. When the A/C was turned on a lot of new air entered from other classes or from the A/C itself and affected the quality of the air in class, so it was a matter of the system.
D. No proper fresh air ventilation when depending on A/C only.
E. There was no consistency in the measurements and sometimes the readings were higher or lower without any specific reason.

F. Experiment One is considered a failed test as it was repeated again with changes done to the way of taking the measurements.

4.1.2 Experiment Two:

Experiment Two was conducted after obtaining the results from Experiment One. It was carried out three months after implementing the green-wall. In Experiment Two changes were done to the way of measuring levels of air components. Instead of placing the equipment in the middle of the classroom, the measurements were taken near the plants and further away from the plants at the same time during the lecture when students were present.

The following Graphs show the average results that were obtained from the female and male classrooms during five days.

Figure 4.7 shows noticeable differences in Total Volatile Organic Compounds when measurements are taken near the green-wall and further away from it. Statistical measurements show a significant difference of .043. When the device was located near the vegetation the TVOC count was much lower than when it was further away from it. This can be attributed to the fact that plants are characterized by their ability to asorb gases such as the generally known Co2 and Carbon monoxide, as well as other harmful gases like formaldehyde, which evaporate from paint and furniture and is harmful when inhaled.

When the device was located further away from the green-wall, the TVOCs level was increased by .043. Even though there is a difference between the two readings, there is a general overall improvement to the IAQ. This is compared to the readings obtained in Experiment One.

The average amount of TVOCs for the female classroom in Experement One was 5629 ppm and the average amount of TVOCs in the male classroom was 6.603ppm which shows very high levels of TVOCs while the avarage amount of TVOCs in Experemental Two was 2403ppm. This shows that the existence of the green wall inside the classroom has improved the IAQ significantly. It can hence be deduced that in order to obtain good results and improved air quality, time should be given to the application of the green-wall for them to take good effect.

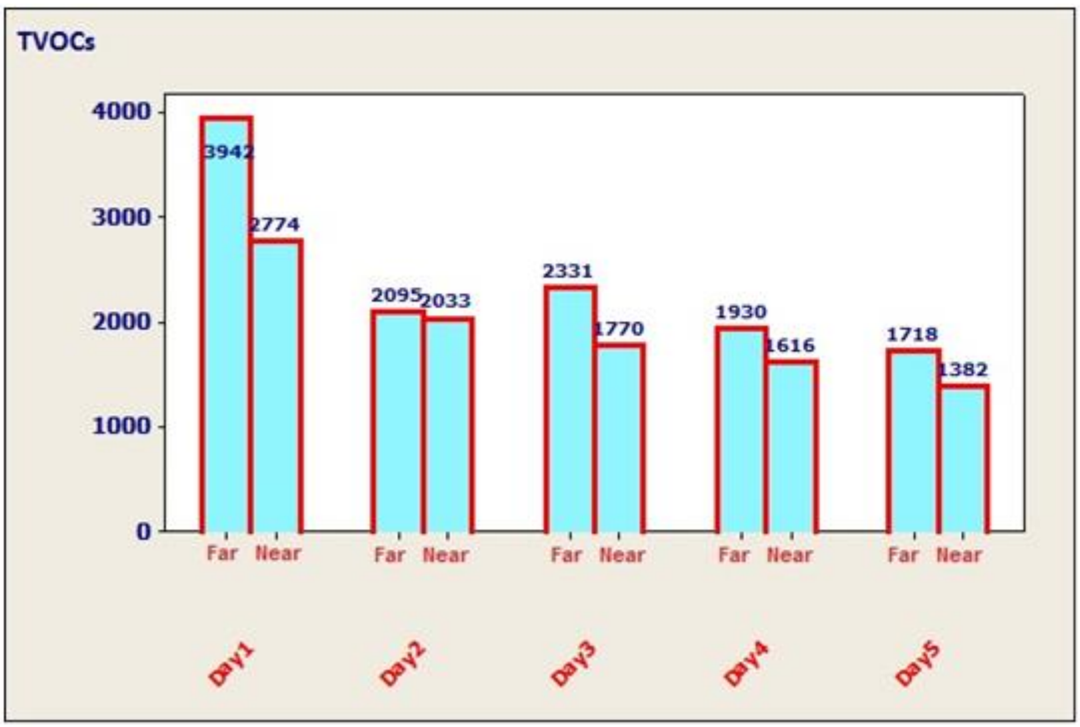

Figure 4.7: The levels of TVOCs near and far the green-wall during five days.

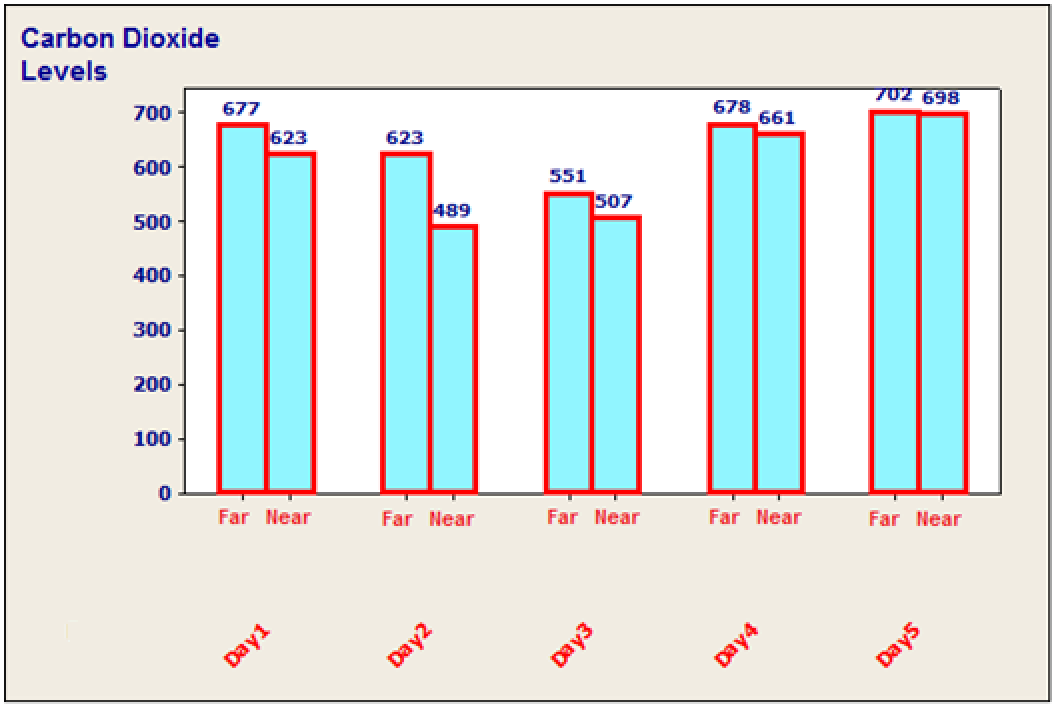

Figure 4.8: The levels of Carbon Dioxide near and far the green-wall during five days.

Figure 4.8 shows clear differences in CO levels when measurements are taken near and further away from the green-wall. Statistical measurements show a significant difference of P>0.05.When the device was located near the plants the CO count was much lower than when it was further awayfrom it.

It is known that plants use CO in the process of photosynthesis;they absorb CO by openings located in their leaves called stomataand can synthesize CO with water using the light energy absorbed by chorophyll to produce sugar and oxygen (biology, 2014).

That explains the lower amount of CO that was detected around the air of the green-wall, in addition to the overall air quality of the classroom when comparing it to Experiment One. As mentioned before CO concentration levels should be not more than 1000 ppm in an interior space (Daisey et al 2003), and by looking to Figure 4.8 the measurement of CO near the green wall were lower than 1000ppm with an average of 595.6ppm which indicate towards healthier air in the classroom.

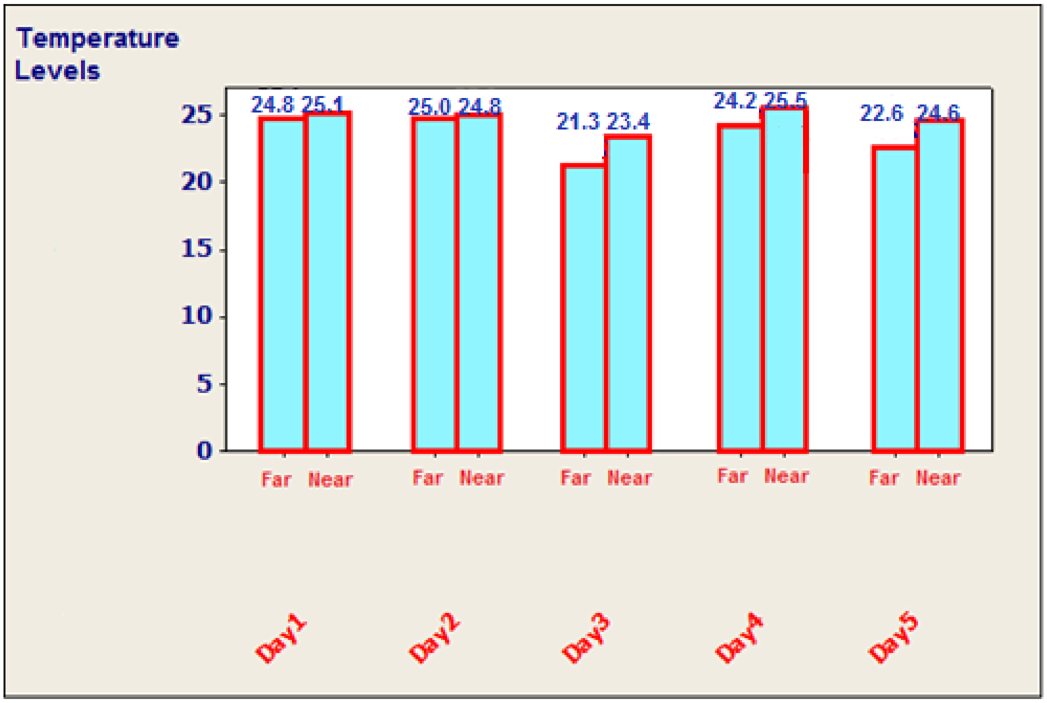

Figure 4.9: The levels of Temperature near and far the green-wall during five days

Figure 4.9 and 4.10 show Graphs for Temperature and Relative humidity levels in the classroom from reading taken both near and further away from the plants. There were minor changes in the measurements of temperature during the five days with no differences recorded in the second day. Statistical calculations showed a significant differences with P=0.05 for the five days, while Relative Humidity shows close levels between far and near green-wall with no significant difference during the five days.

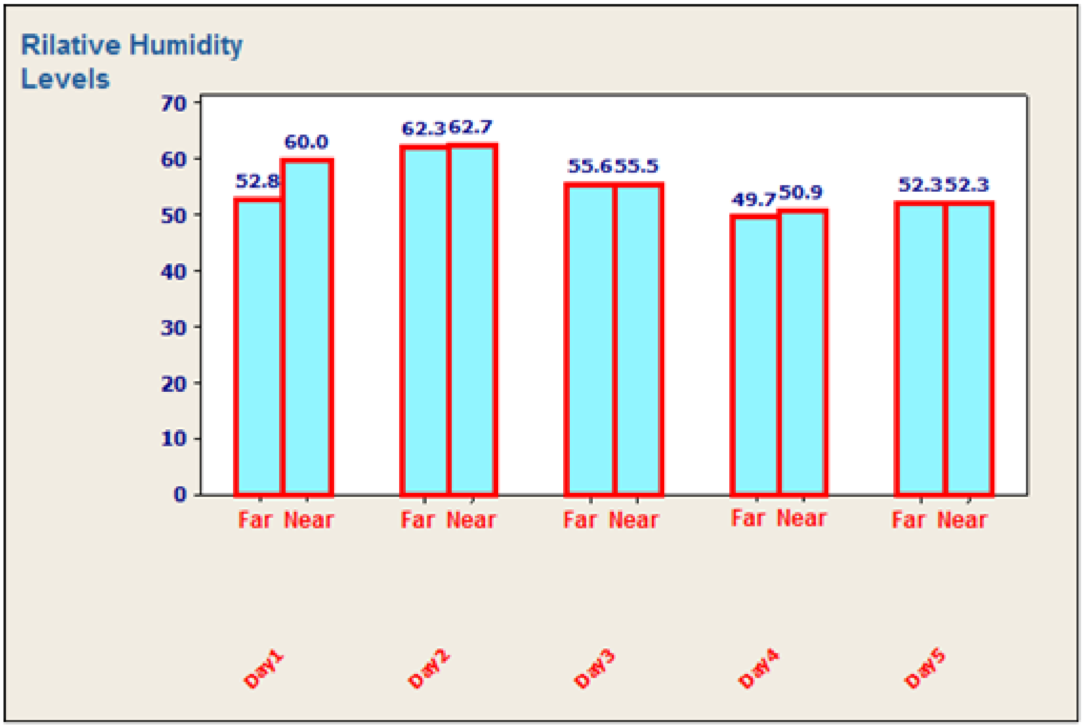

Figure 4.10: The levels of Relative Humidity near and far the green-wall during five days

The measurements of IAQ in Experiment Two were done when the A/C was switched off since A/C was one of the factors that affected the accuracy of the measurements in Experiment One. Minor changes occurred in temperature levels due to the A/C being switched off in addition to plants natural moisture that absorbs and consumes any extra warmth in the air thus decreasing the ambient temperature in any space (Wolverton Environmental,2014). Humidity levels were not affected positively, there were a slight decrease in its levels during the five days, due to plants' transpiration rates. Plans release water vapor from its leaves to the surrounding air during the process of photosynthesis therefore levels of humidity arround the green-wall were higher.

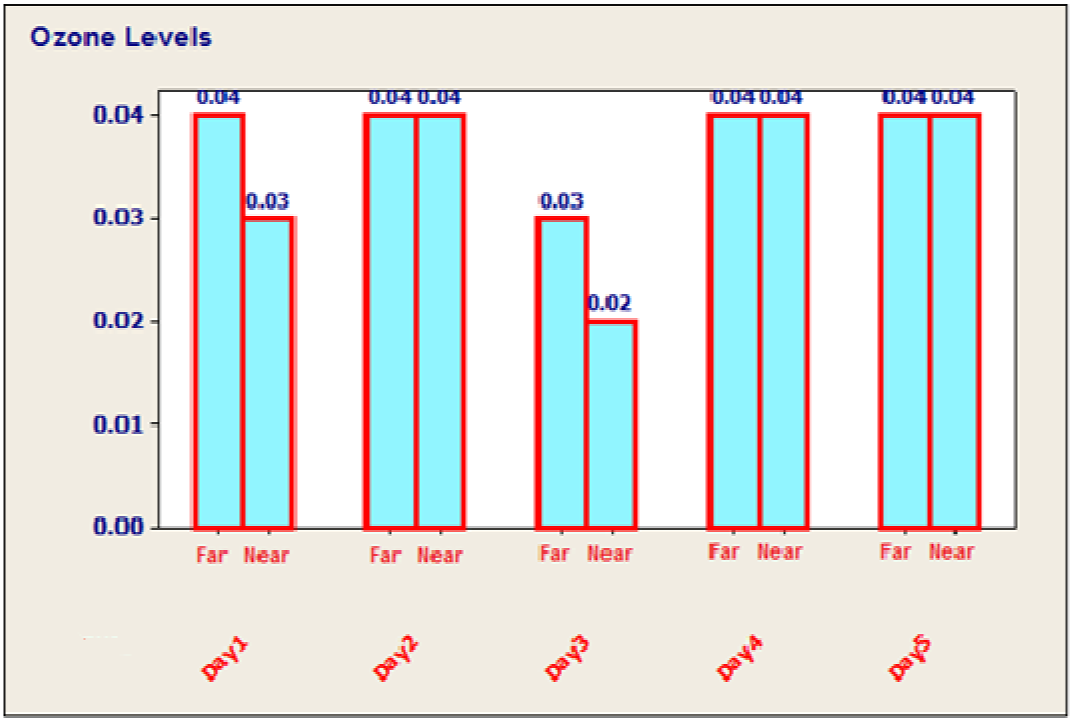

Figure 4.11: The levels of Ozone near and far the green-wall during five days

Ozone measurements illustrated in Figure 4.11 results shows no significant differences near and far the green-wall with P>0.05, the levels in the second, fourth and fifth days kept the same with no changes.

Typical Concentration levels of Ozone should run around 0.01 to 0.05 ppm (parts per million) (airpurifier, 2014) Outdoor air is usually the main source of Ozone concentrations in indoor spaces which is passed in by ventilation systems. In this experiment A/C was the only ventilation system used and that explains the low rates of Ozone. Researchers didn’t arrive at clear results for the ability of plants in absorbing indoor Ozone (Papinchak, 2009).

In this experiment there were no significant results confirmed that plants can mitigate Ozone levels in indoor spaces.

For Total Particulate Matter levels there were no changes in their levels near and further away from the green-wall, that can be illustrated in Figure 4.12 which shows the levels of TPM during the five days.There was no fixed pattern for their level in the air, with no significant differences (P=.588).

The values of average concentrations of PM 10, PM 2.5 in ambient air are 150 and 65 µg/m3.and the total average of TPM in the classroom further away from the green-wall were 67.3µg/m3, while the average amount of TPM near the green wall were 64.6. This shows that values of TPM within the normal concentrations and the slight changes in levels of TPM near and far due to the plants capability of absorbing particulates and work as biological filters. The effect of plants in decreasing TPM due to green-wall small size, couldn't result in cleaning the surrounding air effectively.

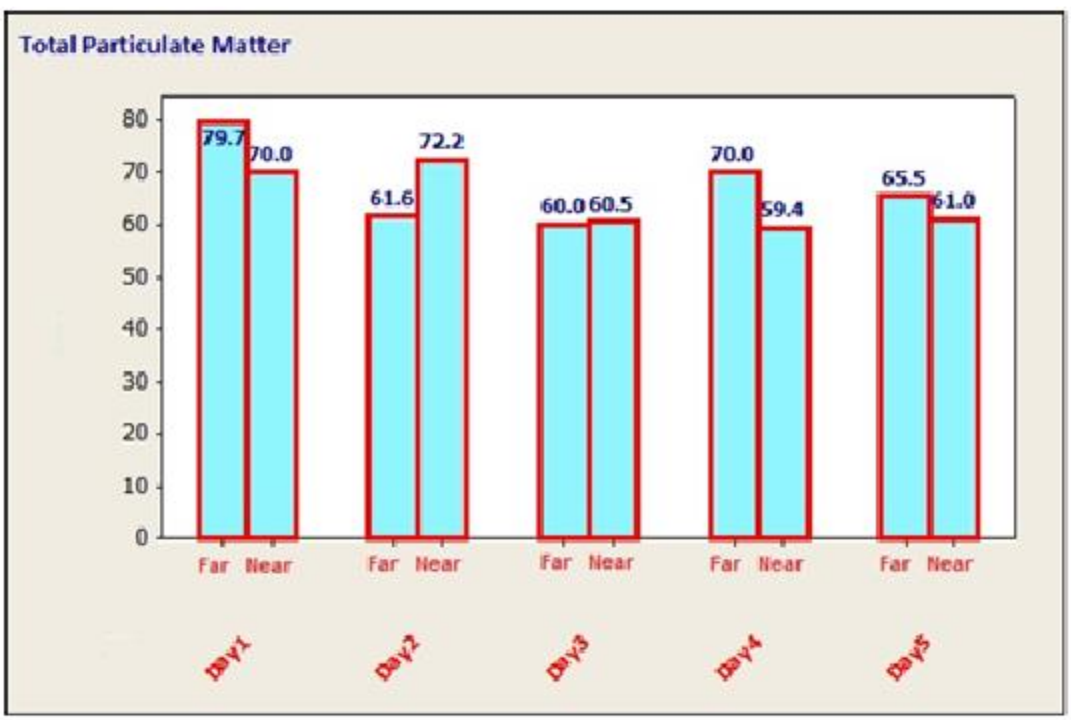

Figure 4.12: The levels of TPM near and far the green-wall during five days

4.2 The Effect of Green-wall on student's performance and productivity.

Students' performance and productivity were assessed by questionnaires and students' grades throughout the semester. Students filled questionnaires before and after placing the green-wall. The yardstick that highlighted the psychological impact of the green-wall were the questionnaires.

As mentioned before, the questionnaires consisted of three parts A, B and C. As for part A, there was a difference in the respondents' opinions in favour of the green-wall. The mean score of section (A) before placing the plants was 2.9 and 3.3 after placing them. There is a mild difference of 0.4 in favour of the green-wall which once again confirms the positive attitude of the green-wall. These results have been achieved as following:

- Section (A) of the questionnaire aimed at assessing the level of comfort before placing the green wall. It was conducted on 24/9/2013 on 50 students. There were 19 male students and 31 female students.
- Since the average score is 2.92, this means that the general trend is concentrated around neutral which means that half the responses were satisfied with the indoor air quality and half were not. Table 4.1 elaborates more on the details.
- The questionnaire was repeated almost three months after placing the green wall on 18/12/2013. The total number of respondents was 37 students, less than the questionnaire before placing the green wall. The results are summarized in the Table 4.2.2

Table 4.1: Questionnaire (A) results before placing green wall

NO.	Question	Very dissatisfactory (1)	Dissatisfactory (2)	Neutral (3)	Satisfactory (4)	Very satisfactory (5)	Mean	Explanations of the Mean
1	Rating the current temperature in the classroom	0	14	19	13	4	**3.1**	**Satisfactory**
2	Do you prefer an increase in your classroom temperature	9	11	12	7	11	**3**	**Neutral**
3	Do you prefer a decrease in your classroom temperature	21	3	9	12	5	**2.5**	**Dissatisfactory**
4	Humidity condition in your classroom	6	4	12	18	10	**3.4**	**Neutral**
5	Fresh air level of the classroom	22	9	7	4	8	**2.3**	**Dissatisfactory**
6.	At the moment do you feel comfortable with the classroom?		5	14	11	5	**3.3**	**neutral**
	Total/ average	64	51	73	66	46	**2.9**	**Dissatisfactory**

Table 4.2: Questionnaire (A) results after placing green wall

NO.	Question	Very dissatisfactory (1)	Dissatisfactory (2)	Neutral (3)	Satisfactory (4)	Very satisfactory (5)	Mean	Explanations of the Mean
1	Rating the current temperature in the classroom	0	10	12	13	4	**3.1**	**satisfactory**
2	Do you prefer an increase in your classroom temperature	6	8	9	12	2	**2.9**	**dissatisfactory**
3	Do you prefer a decrease in your classroom temperature	8	6	13	6	4	**2.8**	**dissatisfactory**
4	Humidity condition in your classroom	3	3	9	10	12	**3.7**	**neutral**
5	Fresh air level of the classroom	1	6	14	12	4	**3.3**	**neutral**
6	At the moment do you feel comfortable with the classroom?	1	5	3	20	8	**3.9**	**satisfactory**
	Total average	21	38	60	73	34	**3.3**	**neutral**

- As mentioned earlier, the mean score of section (A) before placing the plants was 2.9 and 3.3 after placing the plants. The difference is 0.4 which indicates more positive responses and an inclination towards a positive attitude. Although the measurements showed improvements in some of the parameters tested, the major changes and development took place in the psychological parameter as there was a significant increase in the sense of comfort of students.
- According to the survey results, the students were most affected by the temperatures and the comfort level within the classroom. They responded with satisfaction after the green wall was placed and favored it.
- Furthermore, there was an increase from dissatisfaction in the IAQ of the classroom before the green-wall was placed to satisfaction. This is attributed to the positive effect that the vegetation has had on the air circulated around the room and the students have felt it as can be deduced from the survey results.

Section (B) of the questionnaire consisted of questions related to the effect of indoor environment on the students. The results of the two questionnaires, before and after the green-wall, are found in Table 4.3 and 4.4

- The first question related to the temperature shows a clear difference in the responses before and after placing the plants in all the activities enquired about. The level of activity dropped significantly after placing the plants. Switching the AC on and off was reduced after placing the green wall and from this it can be deduced that the vegetation had a positive effect on the temperature by absorbing the heat and leaving after that a cooler indoor environment.

- Furthermore, the results showed a significant drop of 20.1% in the health problems students used to suffer from such as Asthma, Migraines and Allergies. Vegetations and plants have a quality that enables them to absorb dust and other particles. When the green wall was installed these health problems were reduced and can be related to the fact that the green leaf surfaces capture dirt and particulates that affect the breathing of students. Furthermore, reduction of migraines can be related to the visual impact of vegetation that it has on the eye, as continuous eye contact with greenery gives the feeling of relaxation which reduces the feeling of stress.
- The fourth question related to the preference of things added in the classroom to improve indoor environment, showed concentration of responses on new furniture. However, about half the students selected plants as well, and around a quarter of them selected water feature and music.
- Students' were asked for their perception of plants inside the classroom, and most responses pointed to a healthier atmosphere, which rose from 64% to 92%. However, few students pointed to allergies whereas others disliked them or were indifferent. This result shows the positive effect of plants on students and they really prefer to have plants in there classrooms.
- The acoustical comfort question shows that almost half the responses were concentrated on 'very often' with percentage of 54% before locating the green-wall while after placing the plants most responses focused on 'sometimes' with 21%. That means that the green-wall worked as buffer and absorbed unwanted sounds to create a butter atmosphere.
- The following question related to odour also indicated improvement as more students pointed out that they smell undesirable odour rarely after placing the plants which means

that the plants gave a positive smells to the classroom surrounding which were accepted from most of the students. Lily flower is considered to be afragrant plant that was used in the green-wall set, and its flower gives the surrounding air of the classroom a flowery sent which explains the nice odor in the space.

As was made obvious, the actions that indicated discomfort declined significantly after placing the green-wall although the parameters show a significant improvement in air quality as measured by the devices. This proves beyond any doubt that the impact was not only on IAQ but that it was also psychological.

Table 4.3: Questionnaire (B) results before placing green-wall

Questionnaire: Before	Number	%	Av.%
1. Have you done any of the following activities to feel thermally comfortable:			
A. Adding or removing the layer of clothing.	16	32	54%
B. Closing the curtains.	18	36	
C. Switching on or off the air conditioning system.	37	74	
D. Opening the Windows.	37	74	
2. Have you experienced any of the following problems in your classroom:			
A. Migraine.	29	58	30%
B. Asthma.	9	18	
C. Eczema.	7	14	
D. Hay fever (Allergic rhinitis).	8	16	
E. Allergy to dust.	27	54	
F. Allergy to mould.	10	20	
3. Have you experienced any of the following symptoms in your classroom:			
A. Dry eye, Itching eye, tired eye.	28	56	31%
B. Sore or dry throat, Sneezing.	13	26	
C. Unusual downing, Fatigue or tiredness.	9	18	
D. Headache.	32	64	
E. Nausea or upset stomach.	3	6	

F. Dry or itchy skin.	7	14	
G. Nervousness, Tension or irritability.	18	36	
4. Which of the following items do you think can enhance your attitude and concentration in the classroom?			
A. Presence of Plants.	24	48	37%
B. New furniture.	27	54	
C. Water Feature.	7	14	
D. Music.	16	32	
5. What is your perception when you see plants in an interior space:			
A. Allergy.	1	2	19.2%
B. Healthier space.	32	64	
C. Smells.	4	8	
D. Dislike.	1	2	
E. Indifferent.	10	20	
6. Do you usually experience acoustical discomfort e.g. disturbance from people talking, people walking, printers noise, Outdoor noise….etc)?			
A. Never.	1	2	32.6
B. Sometimes.	21	42	
C. Very often	27	54	
7. Do you consider your classroom safe (i.e. Building safety, fire exists, fire fighting element: sprinkler system, smoke detectors, fire extinguisher?			
❍YES 32 ❍No 18			
8. Do you usually smell any undesirable odor in your classroom?			
A. Never.	9	18	33%
B. Sometimes.	39	78	
C. Very often.	2	4	
9. Do you see or smell any dust in your classroom?			
A. Never.	22	44	33%
B. Sometimes.	23	46	
C. Very often.	5	10	

Table 4.4: Questionnaire (B) results after placing green-wall

Questionnaire: After	Number	%	Av.%
1. Have you done any of the following activities to feel thermally comfortable:			
A. adding or removing the layer of clothing.	5	13.5	38%
B. Closing the curtains.	4	10.8	
C. Switching on or off the air conditioning system.	30	81	
D. Opening the Windows.	17	45.9	
2. Have you experienced any of the following problems in your classroom:			
A. Migraine.	3	8	10%
B. Asthma.	2	5.4	
C. Eczema.	5	13.5	
D. Hay fever (Allergic rhinitis).	1	2.7	
E. Allergy to dust.	10	27	
F. Allergy to mould.	1	2.7	
3. Have you experienced any of the following symptoms in your classroom:			
A. Dry eye, Itching eye, tired eye.	6	16.2	13%
B. Sore or dry throat, Sneezing.	3	8	
C. Unusual downing, Fatigue or tiredness.	4	10.8	
D. Headache.	12	24	
E. Nausea or upset stomach.	1	2.7	
F. Dry or itchy skin.	8	21.6	
G. Nervousness, Tension or irritability.	4	10.8	
4. Which of the following items do you think that enhance your attitude and concentration in the classroom?			
A. Presence of Plants.	19	51.3	42%
B. New furniture.	27	72.9	
C. Water Feature.	8	21.6	
D. Music.	8	21.6	
5. What is your perception when you see plants in an interior space:			
A. Allergy.	2	5.4	22%
B. Healthier space.	34	92	
C. Smells.	3	8	
D. Dislike.	1	2.7	
E. Indifferent.	1	2.7	

6. Do you usually experience acoustical discomfort e.g. disturbance from people talking, people walking, printers noise, Outdoor noise….etc)?			
A. Never.	10	27	33%
B. Sometimes.	21	56.7	
C. Very often	6	16.2	
7. Do you usually smell any undesirable odor in your classroom?			
A. Never.	12	32.4	33%
B. Sometimes.	22	59.4	
C. Very often.	3	8	
8. Do you see or smell any dust in your classroom?			
A. Never.	23	62	33%
B. Sometimes.	7	18.9	
C. Very often.	7	18.9	
9. Do you think adding a green wall affected the level of safety of your classroom?			
A. Increased safety level	21	56.7 5	35%
B. Decreased safety level	2	5.4	
C. No change	16	43.2	

Part (C) was dedicated to the lecturers who unfortunately never responded. The only lecturer who responded stated that the green-wall did not cause any change in the classroom and complained that it merely distracted students’ attention. In general, the impression of the lecturer was negative towards placing a green-wall in front of the students. Table 4.2.5 shows lecturer responses.

Table 4.5: Questionnaire (C) results for lecturers after placing green-wall

Questioner (C) for lecturers only:
Did you notice any changes of the following?
1. Your teaching process and class time duration become more pleasant?
A. Increased. B. Decreased. C. No change.
2. Students Attention and Participation?
A. Increased. B. Decreased. C. No change.
3. Students Productivity and performance in classroom work?
A. Increased. B. Decreased. C. No change.
4. Students going on breaks and excuses?
A. Increased. B. Decreased. C. No change.
5. Students Academic Performance?
1. A. Increased. 2. B. Decreased. 3. C. No change.
4. Additional comments (if any): The point to add lively item “green plants” to a class was amazing for all [including me], but…The position of this “green wall” did attract students’ attention more than the board! Some did keep focusing on it “it was just distracting tool!”

Obviously, the teacher was not very impressed by the green-wall and objected to its position in the front of the classroom which seemed to distract the students' attention.

As for students' comments, few students responded by writing the following comments:

5. It is a great idea to put plants in the classroom to improve productivity.
6. The wall should be made colorful
7. I would love to see more green walls throughout the university
8. The design should be better
9. The plants should be distributed in a balanced manner, not only in the corner.
10. Plants look very good. I would like to see them everywhere.
11. It is better to put the plants at the sides and the back of the classroom because they distract attention.
12. Increase the number of plants at the sides of the classroom.
13. I prefer more plants in the classroom.
14. I prefer more plants in the corners
15. I would like more plants, a better design and different place.
16. I prefer more plants, a better design, balanced distribution and more colorful.
17. Plants give a comfortable feeling like a butterfly in the stomach.
18. We need more comfortable chairs
19. I got mild allergy at first, but then I got used to the plants.

Most of these comments pivot around preferring more plants but with an even distribution and a better design. Some mentioned that the plants should be in the back of the classroom to avoid attention distraction.

On the other hand, the academic performance was also affected by placing the green-wall and the students' scores results are shown in Appendix (A). The average score for the classroom with green wall was 79.45 and the average scores for the classes without green walls were: 73.8, 69.6, 77.7 and 76.7. The mean score of the four averages is 74.47%. Hence, the difference between the average score between the scores without the green-wall and the scores with the green-wall is 4.98 or (5) by rounding it. This means there is a significant different between them.

The improvements of the students' grades show the impact of green-wall on students (See figure 4.13 for more details). Healthier air, better thermal comfort classroom environment and the psychological effect of the presence of plants improves students' task performance and eliminates high work stress throughout the semester. A decrease in health symptoms such as Migraine, Headache, Nervousness and Tension improved student's mental functions, so scores significantly benefit from improving indoor air quality.

The strategic use of the indoor comfort plants in the classroom environment lengthened students' attention span and affected how students perceived time, reduced eye strain and provided mental stimulation. In terms of everyday classroom performance, the Figure 4.12 indicating the classroom with indoor plants showed how long students focused on the teacher's presentation of the material and this enhanced creativity, boosted problem-solving abilities and increased production. In classrooms, these findings, indicated that the positive benefits of indoor comfort plants on subjects, including mathematics and science, where problem-solving skills are especially valued.

Researchers have also found that nature effect of these indoor plants can improve reading ability and the calming influence of nature relieves stress and help heal. Those who have a green work environment experience fewer stomach aches and headaches that are exams and tests related. The Green wall created a calm learning atmosphere. It also filtered negativity and put the students at ease and into a positive state of mind, hence the classroom with the green wall have ensured students with higher test scores.

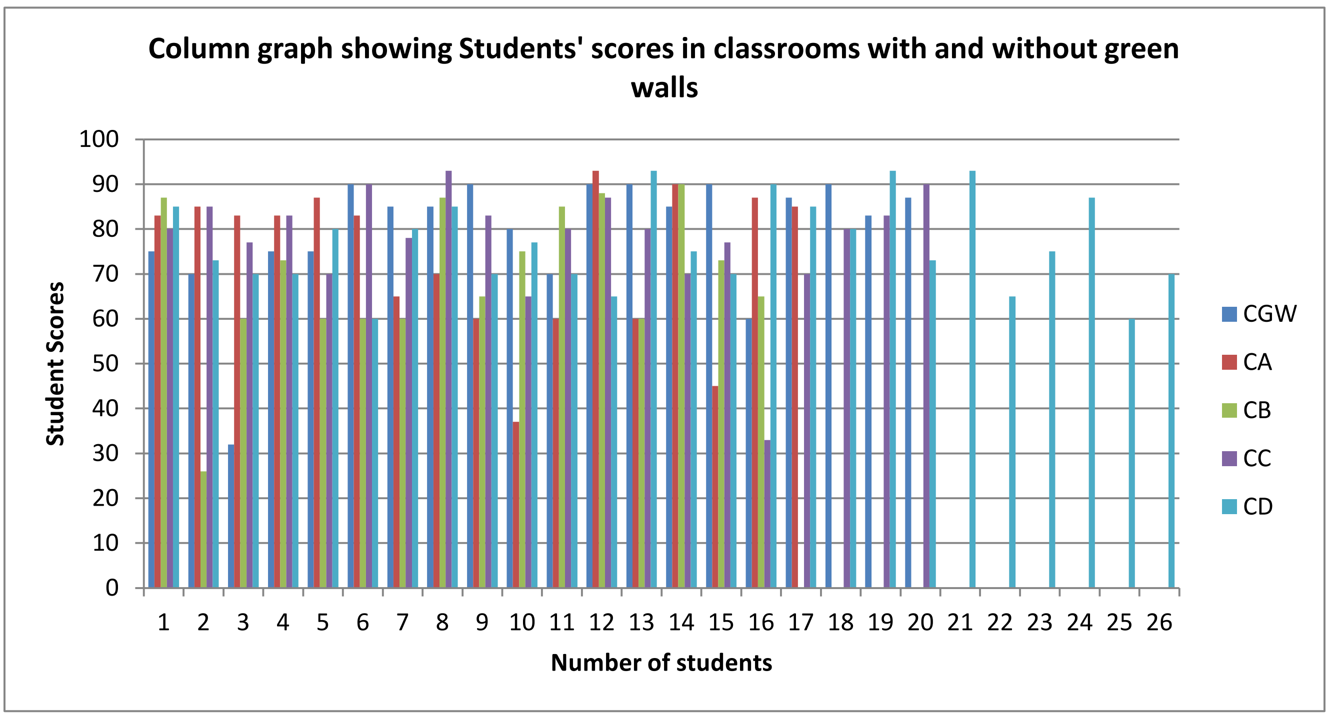

Figure 4.13: Students' scores in classrooms with and without green-wall.

Chapter 5: Conclusion and Recommendations

5.1 Conclusion

Achieving comfortable health in indoor environments became a need for professionals who work in the designing field. There was proper ventilation and light exposure and thus much less health problems were present compared to nowadays, where buildings are treated as isolated blocks. Therefore, improving IAQ and thermal comfort in educational buildings, especially in classrooms, will contribute in the reduction of students' health problems and improve their academic achievements. In the past, buildings whether residential, educational or commercial, were designed to allow exterior interaction with its interior.

The health and well-being benefits of indoor plants are colossal and positive.

It improves on human performances and energy. Spending time in natural environments makes people better at doing their jobs. It also increases energy levels and feelings of vitality and vigor.

Spending time in nature gives students an increased feeling of vitality, increasing their energy levels and making them feel more animated. Their performance levels are, in turn, increased by this improved state of mind. Natural environments create a positive outlook on life, making people feel more alive and active. When people experience increased strenght, they put more of themselves and their energy into their work. Plants can help people to enhance their performance at work, school and at home by heightening their desired vitality and giving them more feelings of added energy. The tranquil effect of natural environments is advantageous to positive work environments by increasing a person's ability to concentrate on all tasks at hand. Being under the influence of plants can increase memory retention up to twenty percent, a recent University of

Michigan study showed (Sewach). The effect of nature in the home and in the workplace serves to enhance both the senses and the mind, improving mental cognition and performance.

Research shows that children who spend time around plants learn better grasp information readily. In addition, being around natural environments improves the ability of children with Attention Deficit Disorder to focus, concentrate, and engage more with their surrounding environment. Keeping plants in a child's learning environment/space supports learning capabilities by helping them to focus and concentrate. This enhances their ability to learn new things and makes it easier for them to absorb and retain information.

Interior plants to clean indoor air of toxic contaminants such as formaldehyde and benzene. Plants also help to improve humidity and minimize dust and other airborne particles in today's energy efficient buildings. Adding plants to the workplace and classroom can enhance and better student and staff health, attendance, satisfaction, and morale and self esteem. Some of the most effective air purifiers are indoor plants for offices and classrooms due to their minimal care requirements and tolerance for office and classroom lighting conditions.

Indoor plants reduce air pollution, along with a number of modern maladies such as stress, illness and even short attention span. Foliage enhances concentration. With so

many breathing bodies in a confined room, high carbon dioxide levels can cause drowsiness, dizziness and headaches and affect your concentration levels in the classrooms and offices. Including indoor plants, it absorbs carbon dioxide through photosynthesis and refreshes the air by releasing oxygen through the foliage.

University of Technology Sydney research found that in air conditioned buildings, plants decreases carbon dioxide levels by about 10 per cent. In buildings that were not air conditioned, this figure rose to 25 percent. Larger plants will absorb more carbon dioxide because of the larger surface area of their foliage.

The leaves of indoor plants balance humidity levels in classrooms and offices. Many plants, especially broad-leaved species, release moisture into the air through evaporation of the moisture in their leaves. Students are almost certain to develop viral infections when humidity levels are too low, and when humidity is too high they are susceptible to eye and fungal diseases. Indoor plants can reduce fatigue, coughs, sore throats and cold-related illnesses by more than 30 per cent. Plants with foliages should be placed on a window bench in the back corner of classrooms and offices.

Indoor plants have also been shown to reduce the number of sick days taken by staff and students and improve job performance in school and office environments. Around one in three workers and students have reported that they have more energy when they have plants around, that plants help them work more productively and that they'd even like to choose the types of plants they have at work or in their classroom and they feel more positive with plants around them.

Indoor plants improve the quality of life in classrooms, offices and homes in many ways such as:-

* They also support the oxygen/carbon dioxide exchange ($O2/CO2$).

* They are environmentally and eco- friendly.

* They offer aesthetic stimulants to children and people in confined rooms.

* They reduce acoustic problems.

* They do not interfere with ventilation systems.

* They minimise blinding effects and the tiring of the eyes in that they reflect yellow/green spectrum, which the human eye response to as being pleasant and relaxing.

* The inclusion of plants requires no change to the structure of the building.

The benefits of indoor plants in the workplace, study place far out-weighs the costs related to maintaining them.

The aim of this research was to study the level of contaminations, temperatures, and comfort within an actual classroom in an educational building. To do so, plants were introduced in a Green-Wall format into the room, and measurements were recorded to mark the effect the vegetation had on the IAQ components such as: TVOCs, $CO2$, CO, Ozone and TPM, in addition to exploring its effect on Indoor Thermal Comfort parameters such as Temperature and Humidity. Furthermore the classroom's Acoustical level was analyzed for achieving better surrounding atmosphere. Finally, the students' psychology and performance were studied as well by examining the effect of vegetation on improving the quality of indoor air.

Experiment method was used to examine the effect of indoor plants on the overall air components. Surveys were given to students in order to evaluate their classroom IAQ and thermal comfort before and after implementing the green-wall.

The Experiment consisted of two scenarios that differ in the way of taking the measurements; the first experiment was carried out by placing the measuring devices in the middle of the classroom, while the second experiment was conducted by placing the devices near and further away from the green-wall.

A green-wall in the classroom can have a positive effect on occupants not only due to the visual comfort it brings, but in reality plants did actually improve the IAQ. The reading parameters results collated by the measuring devices shown in Experiment One and Two were evidence of that.

In experiment one, before placing the green-wall, the levels of TVOCs, Temperatures, Co2 and Acoustical levels were high in comparison to when the measurements were recorded again after the green-wall was placed. There was a minor difference between the two, where there was an improvement on the IAQ as most of the elements recorded showed a reduction in them and hence proves that vegetation has a positive effect on air quality. The little changes were due to the fact that there was high pollution from the wood-work beside the classroom, and not much time was given for the plants to take effect as the measurements were taken almost as soon as they were installed. However, there were noted differences as mentioned. Furthermore, acoustical distractions were also reduced as plants and vegetations create a sound buffer that reduces the noise and echo levels within a room, the leaves of plants attenuate sound by reflecting, refracting and absorbing acoustic energy which leads to fewer echoes. This creates a more calming atmosphere that enables students to focus more on their studies.

In experiment two, measurements were recorded again after a four month period, where the devices were located near and further away from the green-wall. The results showed an even better improvement than experiment one because it was deduced that time was needed for the plants in order for them to contribute to any improvements properly and affect their new habitat, Furthermore the workshop and wood work were stopped working at that time due to the complains from students and lecturers from the smells and dust produced. When compared to experiment one, the differences were drastic as there was a great reduction in the TVOCs, Co2, and Temperature levels. The significant difference in TVOCs was .043 which shows that the plants had a positive effect on absorbing dust and reducing harmful partials in the air. This helps in reducing health problems that students suffer from such as Asthma and Migraine.

Carbon Dioxide levels also reduced with a significant difference of .043 which was reflected later by the students' performance on their grades. It is a known fact that plants absorb CO_2 and produce O_2 in return. The presence of the green-wall lead to increased levels of O_2 which simulate the brain activity and leads to better performances in their work.

Temperature levels when the plants were installed reached to the comfort zone which is 23 degrees, and during that time students found no need to turn the A/C on as they were comfortable in room temperature.

Major changes and development took place in the psychological parameter as there was a significant increase in the sense of comfort of students, that can be illustrated in survey results of section (A) and (B). The mean score of section (A) before placing the green-wall was 2.9, and 3.3 after placing the plants. The difference is 0.4 which indicates more positive responses and an inclination towards a positive attitude. In section (B) of the survey students were asked for their perception of plants inside the classroom, and most responses pointed to a healthier atmosphere, which rose from 64% to 92%.

The psychological impact of green-wall can be shown too by students who claimed that the air quality improved and the difference was really significant. Even though the impact was a psychological one, it gives a pleasant feeling which boosts the sense of comfort in the classroom as evidenced by the students' responses to the questionnaire.

The psychological impact the green wall had on the students led to an improvement in their academic performance as evidenced in the difference between the mean score of the students' tests before and after placing the green-wall. Even though placing the green-wall in front of the students had a distracting effect as was pointed out by the students and a lecturer, if plants become a fixture in classrooms, students will get used to them and they will not distract their attention.

The experiment revealed that greening of buildings should be done according to scale otherwise it will not make any difference. In other words, the ratio of plants inside a building should be calculated well and the plants should be distributed and not concentrated on one side. To make a real difference in the indoor air quality, the amount of plants placed in the classroom should be determined according to scale. In other words, the amount should be suitable to the total area of the class and to the current air pollution in the room.

Green-wall system design should be easy and safe to install, designed to deliver precise low water usage and low maintenance that can hold several amount of plants with a long term plant performance. Having a green wall saves a lot of space, if the same number of plants that used on the living walls were growing in pots on the floor it could probably fill the whole space. It will benefit from a dramatic increase in air filtration and oxygen production and do so using much less valuable floor space

The ideal indoor plants that can be used in UAE interior spaces should be adapted to A/C temperatures, low light conditions, moderate humidity levels and proper watering. Universities as an educational buildings require plants that easy to care of and easy to grow, in educational places they don't have the time or patience to spend on caring for plants or need a plant that survives well with low expenses.

5.2 Recommendations

After reaching the above conclusions, the following recommendations were proposed:

1. Plants should be an integral part of classroom in an abundant amount so that they improve air quality, create a sense of pleasure, and improve students' academic performance.
2. Plants should be present in classrooms all the time in the front, sides and back so that students will get used to them and not get distracted by them.
3. In designing educational buildings the presence of locating workshops should be taken into consideration so that classrooms are not affected by particles and air pollution.
4. The building industry must accept the need to internally purify, revitalize and recycle air. This is important for energy saving and to reduce the vulnerability of indoor air to biological and/or chemical agents that could be present in the outdoor air
5. Plants as a mitigation method could serve as a cost-effective tool in the developing world where expensive pollution mitigation technology may not be economically feasible.
6. Plants need more time to affect the surrounding air quality in a room especially if the room air was highly polluted.

7. Plants can generally be used to enhance the aesthetic environment and the air quality inside buildings, but care must be taken to account for potential allergies, the use of fertilizers and pesticides indoors, adequate ventilation and air flow, and the level of moisture maintained for the plants -- all factors that can affect the building and its occupants.

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Appendix (A): Students Scores in the Classroom With and Without Green-wall

Table A.1: Students Scores in the Classroom with Green Wall

No.	1st test	2nd test	3rd test	Total
1	28	13	34	75
2	29	13	28	70
3	11	11	10	32
4	32	11	32	75
5	32	10	33	75
6	35	18	37	90
7	33	17	35	85
8	32	17	36	85
9	33	19	38	90
10	33	15	32	80
11	29	10	31	70
12	36	18	36	90
13	36	19	35	90
14	33	17	35	85
15	36	18	36	90
16	25	11	24	60
17	35	14	38	87
18	34	18	38	90
19	32	15	36	83

20	32	18	37	87
Average score				79.45

Table A.2: Students Scores in the classroom without green-walls (Class A)

NO.	**1st test**	**2nd test**	**3rd test**	**Total**
1	34	18	31	83
2	34	18	33	85
3	33	18	32	83
4	37	18	28	83
5	33	19	35	87
6	35	16	32	83
7	25	12	28	65
8	30	15	25	70
9	25	13	22	60
10	15	0	22	37
11	25	11	24	60
12	36	19	38	93
13	25	11	24	60
14	35	19	36	90
15	15	15	15	45

16	36	18	33	87
17	33	18	34	85
Average score				73.88

Table A.3: Students Scores in the classroom without green-walls (Class B)

NO.	**1st test**	**2nd test**	**3rd test**	**Total**
1	34	18	35	87
2	15	4	7	26
3	25	10	25	60
4	29	14	30	73
5	26	9	25	60
6	25	10	25	60
7	30	11	19	60
8	37	18	32	87
9	27	13	25	65
10	30	14	31	75
11	34	17	34	85
12	35	17	36	88
13	22	14	24	60
14	36	18	36	90

15	30	15	28	73
16	28	12	25	65
Average score				69.6

Table A.4: Students Scores in the classroom without green-walls (Class C)

NO.	**1st test**	**2nd test**	**3rd test**	**Total**
1	30	17	33	80
2	32	19	34	85
3	31	14	32	77
4	33	16	34	83
5	25	15	30	70
6	36	19	35	90
7	31	17	30	78
8	37	19	37	93
9	31	18	34	83
10	28	8	29	65
11	29	15	36	80
12	35	18	34	87
13	34	14	32	80
14	30	10	30	70

15	30	13	34	77
16	5	10	18	33
17	26	14	30	70
18	32	12	36	80
19	27	18	33	83
20	29	18	37	90
Average score				77.7

Table A.5: Students Scores in the classroom without green-walls (Class D)

NO.	**1st test**	**2nd test**	**3rd test**	**Total**
1	36	17	32	85
2	28	15	30	73
3	27	15	28	70
4	29	12	29	70
5	33	15	32	80
6	25	12	23	60
7	32	14	34	80
8	34	18	33	85
9	28	15	27	70

10	31	15	31	77
11	22	17	31	70
12	23	13	29	65
13	37	19	37	93
14	32	12	31	75
15	26	18	26	70
16	36	18	36	90
17	32	17	36	85
18	29	17	34	80
19	38	17	38	93
20	30	14	29	73
21	38	18	37	93
22	26	14	25	65
23	30	13	32	75
24	32	18	37	87
25	27	10	23	60
26	29	11	30	70
Average score				76.7

Appendix(B): IAQ and Thermal Comfort Measurements Before and After green-wall

Table B.1: IAQ and thermal comfort measurements in females' classroom without green-wall

Females		**Measured Components**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**
No Green Wall	With A/C	TVOCs	6327	8321	5789	5091	2329
		Carbon Dioxide	1008	1852	1566	1550	1513
		Ozone	0.03	0.04	0.04	0.07	0.06
		Carbon Monoxide	0.6	0.1	0.0	0.0	0.0
		Total Particulate Matter	107.1	113.6	112.3	125.6	113
		Temperature	20.1	21.9	21.1	22.1	23.7
		Relative Humidity	69.7	71.6	61.0	49.4	47.5
		Max Acoustical levels	79	81.1	74.6	77.9	80
	No A/C	TVOCs	5307	6812	5764	6240	2329
		Carbon Dioxide	1028	1772	1500	1560	1616
		Ozone	0.02	0.03	0.04	0.04	0.03
		Carbon Monoxide	0.4	0.3	0.1	0.2	0.3
		Total Particulate Matter	106.4	110.5	119.6	120.6	119
		Temperature	23.1	23.9	24	25	23
		Relative Humidity	79	71	67	59	66.7

Table B.2: IAQ and Thermal Comfort measurements and its significant deference in female's classroom with green-wall

Females		**Measured Components**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**S.D**
With Green Wall	With A/C	TVOCs -ppb	6300	2826	5450	5980	6205	.91
		Carbon Dioxide -ppb	1650	1549	1550	1591	1722	.40
		Ozone- ppb	0.03	0.03	0.03	0.04	0.03	**.05**
		Carbon Monoxide- ppb	0.4	0.9	0.4	0.4	0.6	**.05**
		Total Particulate Matter- µg/m3	104.2	117.2	118.5	102.5	122.9	.91
		Temperature- C°	20	20.7	21	20.5	20	**.05**
		Relative Humidity- %	65	65.5	70	67.7	77	.25
		Max - Acoustical Levels- dB	70	72.2	70.5	70	71	**.009**
	No A/C	TVOCs -ppb	5936	4222	6689	5780	6907	.46
		Carbon Dioxide -ppb	1630	1581	1660	1690	1504	.34
		Ozone- ppb	0.05	0.04	0.05	0.06	0.05	.01
		Carbon Monoxide- ppb	0.2	0.9	0.6	0.6	0.6	**.05**
		Total Particulate Matter- µg/m3	100.4	122	120.5	130.3	120	.25
		Temperature- C°	23.9	21.9	23	22.5	22.8	**.04**
		Relative Humidity- %	63.4	73.9	65.9	77	70.2	.91

Table B.3: IAQ and Thermal Comfort measurements in male's classroom without green-wall

Males		**Measured Components**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**
No Green Wall	With A/C	TVOCs	5943	5934	7549	4761	5638
		Carbon Dioxide	654	662	454	897	698
		Ozone	0.03	0.03	0.03	0.03	0.05
		Carbon Monoxide	0.4	0.4	0.4	0.3	0.4
		Total Particulate Matter	110.8	102.7	99.8	100	115
		Temperature	20.7	20.7	20.0	21	20.5
		Relative Humidity	77.4	77.3	78.7	67	65.6
		Max Acoustical Levels	80	81.5	80.4	79	79.6
	No A/C	TVOCs	6642	7912	7430	6551	6636
		Carbon Dioxide	754	782	786	877	690
		Ozone	0.02	0.02	0.03	0.02	0.02
		Carbon Monoxide	0.3	0.3	0.2	0.3	0.4
		Total Particulate Matter	115.9	99.6	98.9	107	133
		Temperature	23	24.2	23.3	21	22
		Relative Humidity	67	76.8	68	67.8	61

Table B.4: IAQ and Thermal Comfort measurements and its significant deference in male's classroom with green-wall

Males		Measured Components	Day 1	Day 2	Day 3	Day 4	Day 5	S.D
With Green Wall	With A/C	TVOCs -ppb	7500	6780	6034	6745	7710	**.05**
		Carbon Dioxide -ppb	588	600	566	570	590	.15
		Ozone- ppb	0.04	0.05	0.04	0.04	0.03	.17
		Carbon Monoxide- ppb	0.0	0.2	1.0	0.7	0.3	.6
		Total Particulate Matter- μg/m3	129.1	110	117	120	112	**.04**
		Temperature- C^o	20.1	21	21.5	20	20	.8
		Relative Humidity- %	72.7	70	77	67	75.4	.5
		Max - Acoustical Levels- dB	70	72.1	70.5	70.1	71	**.009**
	No A/C	TVOCs -ppb	6700	5680	6045	6123	6717	.175
		Carbon Dioxide -ppb	580	656	523	687	534	.009
		Ozone- ppb	0.03	0.04	0.04	0.04	0.03	.011
		Carbon Monoxide- ppb	0.2	0.3	0.3	0.3	0.4	1.2
		Total Particulate Matter- μg/m3	133	130	114	111	120	.209
		Temperature- C^o	23.1	25	23.5	22	25	.207
		Relative Humidity- %	52.7	70	66	56	78	.602

Appendix (C): IAQ and Thermal Comfort Measurements Near and Far green-wall

Table C.1: The average measurements of IAQ and Thermal Comfort and its significant deference in male's and female's classroom far from green-wall

	Measured Components	Day 1	Day 2	Day 3	Day4	Day5	Significant difference
Far from Green-Wall	TVOCs	3942	2095	2331	1930	1718	**.043**
	Carbon Dioxide	677	623	551	678	702	**.043**
	Ozone	0.04	0.04	0.03	0.04	0.04	.157
	Carbon Monoxide	0.7	1.2	0.5	0.8	2.1	.276
	Total Particulate Matter	79.7	61.6	60.0	70	65.5	.588
	Temperature	25.1	24.8	23.4	25.5	24.6	**.05**
	Relative Humidity	52.8	62.3	55.6	49.7	52.3	.14

Table C.2: The average measurements of IAQ and Thermal Comfort in male's and female's classroom near from green-wall

	Measured Components	**Day 1**	**Day 2**	**Day 3**	**Day4**	**Day5**
Near Green-Wall	TVOCs	2774	2033	1770	1616	1382
	Carbon Dioxide	623	489	507	661	698
	Ozone	0.03	0.04	0.02	0.04	0.04
	Carbon Monoxide	0.6	1.4	0.3	0.7	1.3
	Total Particulate Matter	70	72.2	60.5	59.4	61
	Temperature	24.8	25	21.3	24.2	22.6
	Relative Humidity	60	62.7	55.5	50.9	52.3

Appendix (D): Thermal Comfort and Indoor Air Quality Questionnaire before Locating the Green-wall.

Before

Date: / / 2013	Time:
Module Name:	Gender: Male / Female
Total GPA:	Major:
Country:	
Select your Class Rank: freshman sophomore junior senior	

Section A:

Please answer the following questions as ***1 being the least satisfied and 5 being fully satisfied.***

1. Rating the current temperature of your classroom?

   ❍1 ❍2 ❍3 ❍4 ❍5

2. Do you prefer an increase in your classroom temperature?

   ❍1 ❍2 ❍3 ❍4 ❍5

3. Do you prefer a decrease in your classroom temperature?

   ❍1 ❍2 ❍3 ❍4 ❍5

4. Humidity condition in your classroom?

   ❍1 ❍2 ❍3 ❍4 ❍5

5. Fresh air exchange (refreshing) level of the classroom?

   ❍1 ❍2 ❍3 ❍4 ❍5

6. At the moment do you feel comfortable with the classroom environment (Temperature, Humidity, Background sound level)?

❍1 ❍2 ❍3 ❍4 ❍5

Section B:

Please answer the following questions by choosing the best answer, you can choose more than answer.

1. Have you done any of the following activities to feel thermally comfortable:

   A. Adding or removing the layer of clothing.
   B. Closing the curtains.
   C. Switching on or off the air conditioning system.
   D. Opening the Windows.

2. Have you experienced any of the following problems in your classroom:

   A. Migraine.
   B. Asthma.
   C. Eczema.
   D. Hay fever (Allergic rhinitis).
   E. Allergy to dust.
   F. Allergy to mould.

3. Have you experienced any of the following symptoms in your classroom:

   A. Dry eye, Itching eye, tired eye.
   B. Sore or dry throat, Sneezing.
   C. Unusual downing, Fatigue or tiredness.
   D. Headache.
   E. Nausea or upset stomach.
   F. Dry or itchy skin.
   G. Nervousness, Tension or irritability.

4. <u>Which of the following items do you think that can enhance your attitude and concentration in the classroom?</u>

   A. Presence of Plants.
   B. New furniture.
   C. Water Feature.
   D. Music.

5. <u>What is your perception when you see plants in an interior space:</u>

   A. Allergy.
   B. Healthier space.
   C. Smells.
   D. Dislike.
   E. Indifferent.

6. <u>Do you usually experience acoustical discomfort e.g. disturbance from people talking, people walking, printers noise, Outdoor noise….etc)?</u>

   A. Never.
   B. Sometimes.
   C. Very often

7. <u>Do you consider your classroom safe (i.e. Building safety, fire exists, fire fighting element: sprinkler system, smoke detectors, fire extinguisher?</u>

   ❍YES ❍No

8. <u>Do you usually smell any undesirable odor in your classroom?</u>

   A. Never.
   B. Sometimes.
   C. Very often.

9. <u>Do you see or smell any dust in your classroom?</u>

   A. Never.
   B. Sometimes.
   C. Very often.

<u>Appendix (E):</u> Thermal Comfort and Indoor Air Quality Questionnaire after Locating the Green-wall.

Indoor Air Quality & Indoor Climatic Conditions Questionnaire

<u>After</u>

Date: / / 2013	Time:
Module Name:	Gender: Male / Female
Total GPA:	Major:
Country:	
Select your Class Rank: freshman sophomore junior senior	

<u>Section A:</u>

Please answer the following questions as ***<u>1 being the least satisfied and 5 being fully satisfied.</u>***

1. Rating the current temperature of your classroom during the last month?

   ❍1 ❍2 ❍3 ❍4 ❍5

2. Do you prefer an increase in your classroom temperature?

   ❍1 ❍2 ❍3 ❍4 ❍5

3. Do you prefer a decrease in your classroom temperature?

   ❍1 ❍2 ❍3 ❍4 ❍5

4. Humidity condition in your classroom during the last month?

   ❍1 ❍2 ❍3 ❍4 ❍5

5. Fresh air exchange (refreshing) level of the classroom during the last month?

❍1 ❍2 ❍3 ❍4 ❍5

6. At the moment do you feel comfortable with the classroom environment (Temperature, Humidity, Background sound level)?

❍1 ❍2 ❍3 ❍4 ❍5

Section B:

Please answer the following questions by choosing the best answer. You can choose more than one answer.

1. Have you done any of the following activities to feel thermally comfortable during the last month:

   A. Adding or removing the layer of clothing.
   B. Closing the curtains.
   C. Switching on or off the air conditioning system.
   D. Opening the Windows.

2. Have you experienced any of the following problems in your classroom during the last month:

   A. Migraine.
   B. Asthma.
   C. Eczema.
   D. Hay fever (Allergic rhinitis).
   E. Allergy to dust.
   F. Allergy to mould.

3. Have you experienced any of the following symptoms in your classroom during the last month:

   A. Dry eye, Itching eye, tired eye.
   B. Sore or dry throat, Sneezing.
   C. Unusual downing, Fatigue or tiredness.
   D. Headache.

E. Nausea or upset stomach.
F. Dry or itchy skin.
G. Nervousness, Tension or irritability.

4. Which of the following items do you think that can enhance your attitude and concentration in the classroom?

   A. Presence of Plants.
   B. New furniture.
   C. Water Feature.
   D. Music.

5. What is your perception when you see plants in an interior space:

   A. Allergy.
   B. Healthier space.
   C. Smells.
   D. Dislike.
   E. Indifferent.

6. Do you usually experience acoustical discomfort e.g. disturbance from people talking, people walking, printers noise, Outdoor noise….etc)?

   A. Never.
   B. Sometimes.
   C. Very often

7. Do you usually smell any undesirable odor in your classroom?

   A. Never.
   B. Sometimes.
   C. Very often.

8. Do you see or smell any dust in your classroom?

   A. Never.
   B. Sometimes.
   C. Very often.

9. Do you think adding the green wall affected the safety level of your classroom?

A. Increased safety levels.
B. Decreased safety levels.
C. No change.

Any Comments:

Section C (After) :

This section is only for Lecturers.

Did you notice any changes of the following:

1. Your teaching process and class time duration become more pleasant?

    A. Increased.
    B. Decreased.
    C. No change.

2. Students Attention and Participation?

    A. Increased.
    B. Decreased.
    C. No change.

3. Students Productivity and performance in classroom work?

    A. Increased.
    B. Decreased.
    C. No change.

4. Students going on brakes and excuses?

    A. Increased.

B. Decreased.
C. No change.

5. Students Academic Performance?

A. Increased.
B. Decreased.
C. No change.

Additional comments (if any):

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