In the Eye of the Flourish Wheel: An Assessment of Users' Health, Well-Being and Productivity in University Research Rooms

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Abstract: Indoor Environmental Quality (IEQ) is an immense concern for people's wellness. With this in mind, the central argument in this research is that the IEQ in a university research room impacts users and their health, well-being and productivity. In addition, the present study relies on the Flourish Wheel to enhance the environment using the Biophilic Design approach, which in turn influences users' satisfaction and work performance in five research rooms at Brunel University London. These rooms are situated in the same outdoor environment of a single university campus, but house multi-disciplinary occupants and vary in construction age, size, methods of ventilation and mode of thermostatic control. The research study presented in this paper firstly investigated, the role of IEQ factors and sub-factors on occupants' health, well-being, and productivity. Secondly, the research evaluated the possibility of improving the indoor workplace environment using Biophilic Design patterns. The most prominent finding that emerge from this study is that the qualities of the five critical aspects of IEQ have significantly positive correlations with the occupants' wellness. Another significant result of the study is that the 14 Biophilic Design framework patterns can holistically offer different ways to improve the research rooms based on various environmental issues. The findings proposed in this study could be valuable both for design practitioners and academic researchers.

Keywords: Flourish Wheel; Biophilic Design; Academic Workplaces; Indoor Environmental Quality.

1. **Introduction**

Humans spend most of their time indoors and a large proportion of the world's community live in urban areas and works in an office environment (ASHRAE 1993). There has been a vital global shift in the economy from the manufacturing sector towards the service and knowledge-based industries, which operate in indoor office environments (Haynes 2008; WGBC 2014). Hence, it is becoming essential to understand the indoor office environment and its effect on occupant wellness.

The recent trend of designing and building research rooms (or study rooms) in colleges and universities has led to renewed interest in the concept of "open-plan offices"[1] because of its use advantages favorable economic outcomes. Moreover, these research spaces are seen as valued parts of the university environment, contributing significantly to the quality of research outputs (Walford, 1983). However, one of the most significant challenges in designing and building such spaces is achieving a healthy environment, especially for those researchers who spend most of their time working in the research rooms.

The influence of environmental design on people's wellbeing and productivity has been studied in some settings, such as open-plan offices in hospitals and elementary schools. However, Biophilic Design in university research rooms remains understudied and it therefore warrants a closer investigation.

In the 20th century, the seminal work of Maslow (Maslow, 1943) used the Human Needs Theory to address the poor IEQ, which impairs people's health, well-being and productivity (see also Vernon and Bedford, 1930, on air quality). Since then, the influence of the indoor environment on workplace productivity has been widely studied. A strand of the literature addresses the direct effects of IEQ on human comfort (see, for example, Bordass, Bromley and Leaman, 1993; Leaman and Bordass, 1999; Bordass et al., 2001; Collinge et al., 2014; Tsushima, Tanabe and Utsumi, 2015). Another strand of scholarship concerns

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[1] *Open-plan offices* refer to the offices designed and built for the daily research work (ISO, 2009) of groups of researchers (e.g. postgraduate students, post-doctoral researchers and research staff)

the direct impact of IEQ on wellbeing (Mackerron and Mourato, 2013; World Green Building Council, 2014).

Traditionally, these papers have considered five physical factors that influence occupants' health, well-being and productivity, namely, thermal comfort (Fanger, 1970; Tanabe, Nishihara and Haneda, 2007; Djongyang, Tchinda and Njomo, 2010; Lan, Wargocki and Lian, 2011; Kaushik *et al.*, 2020); indoor air quality (Wargocki, 2000; Fisk, Black and Brunner, 2012; Mujan *et al.*, 2019), lighting comfort (Hopkinson et al., 1966, Alrubaih et al., 2013; Poria et al., 2013; Zhang *et al.*, 2020), acoustic comfort (Banbury and Berry, 2005, Wong and Mui, 2006; Di Blasio *et al.*, 2019), and office layout (Laing et al., 1998; Haynes et al., 2009; Candido *et al.*, 2019).

The above studies show the impact of IEQ factors on the occupants' satisfaction and productivity. However, the application of Biophilic Design, including green architecture solutions, is not significantly covered in the standard methods of improving the IEQ of existing buildings.

Broadly, humans are inexorably tied to the larger natural world, and the human-nature relationship is fundamental and instinctive (Kellert et al., 1993; Wilson, 1984). This relationship is the basis for the Biophilic Design hypothesis, and by extension, a basic principle of Biophilic Design (Kellert, S.R., 2012; Kellert et al., 2011). Thus, if the indoor environment constructed with healthy and prosperous natural spaces benefits our basic needs and wellbeing, as the Biophilic Design hypothesis claims, then nowhere is the need for ensuring a good and healthy connection to nature more critical than in the places where people live, work and spend the majority of their daily lives.

In this vein, a study by peters and D'Penna (2020) has analysed almost 30 studies and they concluded that nearly none of the relevant studies included a reference to "Biophilia" or "Biophilic Design", nor did they mention the Biophilic patterns that the authors have categorized them in this paper.

Motivated in part by these observations, the research reported in this paper was conducted in response to the need to enrich the existing knowledge of the role of Biophilic design in human health and wellbeing, by shedding light on the indoor environmental conditions of open-plan research offices in five different buildings at the Brunel University London, and to assess the significance of using Biophilic Design patterns to improve the IEQ factors in the buildings in question.

Recently, a broader perspective has been adopted by Sanchez et al. (2018) who, argue that Biophilic Design features have been identified as critical drivers of well-being and performance in the workplace (see also Al Horr et al. 2016; Soga et al. 2016). For instance, wooden interiors, a propitious temperature and physical activity promote an independent impact on users' cognitive function, performance, health and well-being (Cooper, 2011). Similarly, Al-Dmour et al. (2020) and Clements-Croome et al. (2021) suggest that Biophilia[2] helps control the quality of the indoor environment.

Bringing elements of the natural environment or greenery within the workplace positively impacts the occupants' productivity asit reduces the stress in occupants (Kellert, Heerwagen and Mador, 2008; Gray and Birrell, 2014a). Further, interior plants improve indoor air quality (Lohr, Pearson-Mims and Goodwin, 1996). As noted above, they help minimise the pollution in the office by reducing the volatile organic compounds produced by various indoor furniture or synthetic materials (Grinde and Patil, 2009). The passive viewing of natural stimuli through windows can reduce discomfort and improve the positive mood of the occupants (Heerwagen and Heerwagen, 2003).

A field study has shown that occupants with a window view of nature were more satisfied than occupants with a view only of the built environment (Kaplan and Kaplan, 1989). Generally, nature helps to minimise stress levels and anxiety even when only seen from a window. Windows with views of nature and plants have been mentioned as helpful in reducing occupants' tension and anxiety and increasing their productivity and well-being (Chang and Chen, 2005). An American psychological study claims that Biophilic Design also helps balance office temperature and humidity levels, which can be achieved by using plants and radiant surface materials (Kellert, Heerwagen and Mador, 2008).

[2] Wilson first described the concept of Biophilia as "the innately emotional affiliation of human beings to other living organisms. Innate means hereditary and hence part of ultimate human nature."-(Wilson, 2006)

2. Post-Occupancy Evaluation

This study investigated how the qualitative environmental factors of health, well-being and productivity) can be affected by the environmental factors (IEQ) in university research rooms that enhance the environment using the Biophilic design approach. The study surveyed the academic researchers in five different research rooms at Brunel University to identify the key challenges, opportunities and barriers to improving university research rooms.

The first part of this study focuses on the indoor environmental conditions of open-plan research rooms as they pertain to health, well-being, and productivity. Table (1) shows the main strands of the last decade's POE work that has been developed by academic researchers and preceded the Flourish Model in understanding the occupant's well-being and used to assess factors in workplaces:

Table 1 about here

The second phase, however, involved adopting the evaluation model of Derek Clements-Croome (2016, 2018, 2021), who created and developed the Flourish Wheel, a tool designed to help create environments that help people Flourish in living and work. The Flourish Wheel is used as a POE (Post Occupancy Evaluation) for the buildings to evaluate the actual situation form three points of view, the environmental factors (objective design parameters, subjective design parameters), perceptions and economic consequences of the environment, as shown in figure (1).

Figure 1 about here

Using this Flourish Model can be conducted through the following steps:

1. Work with client needs with Flourish Model aspects.
2. Use a sample survey of occupants using questions based on the Flourish wheel in Figure (1).
3. Use a multi-factor decision-making approach to analyses results and derive a predesign map using the Flourish Wheel.
4. At the POE stage, collect data from the environment, and people repeat the analysis.
5. Recommend any changes using Biophilic Design.

Together, as for enhancing the chosen university rooms, this research is going to follow the 14 Patterns of Biophilic Design milestone. It aims to create spaces that are inspirational, refreshing, healthy, as well as integrative with the functionality of the place and the (urban) ecosystem. This milestone also helps in understanding how to implement Biophilic design in three pillars; First, Nature in the space, which is about the incorporation of plants, water and animals into the built environment, second, the Natural Analogues, which include the materials and patterns that evoke nature, and finally, Nature of the space which explains the psychological and physiological responses to spatial configurations.

6. Based on the previous literature, the researcher connected the 14 patterns of Biophilic Design and the IEQ factors and sub-factors that primarily affect the occupants' health, well-being and productivity, as in Table 2.

Table 2 about here

In the next stage of this research, four models were estimated through regression analysis to assess the direct impact of the IEQ factors on productivity. The final stage used correlation analysis to evaluate the potential effects of improving conditions in these indoor workplaces according to the patterns of Biophilic Design.

2. Occupant surveys

To conduct an IEQ assessment on productivity and health from the occupants' point of view and to suggest the potential of adapting the 14 Biophilic Design patterns, a cross-sectional survey was designed to answer the research question: How do the IEQ factors and sub-factors affect the occupants in the open-plan workplaces, which have the same outdoor but different indoor environments. The questionnaire was administered between January and February 2020. It should be noted that an ethical approval for the study was obtained from the ethics department of the university before sending the invitation link to the occupants of the workplaces in question.

To explain the relationship between IEQ factors and the Flourish Wheel sub-factors, figure 2 below shows that the Flourish model focuses on how fresh or polluted the air in the office environment is for the Indoor Air Quality at the same time, the thermal comfort is mainly concerned with the level of both temperature and humidity; this view is supported by (Wolkoff 2018, Langer et al., 2016, Shahzad et al., 2018). Furthermore, the absence of fresh air with an environment full of pollution, create higher rates of dissatisfaction from occupants and a range of health problems (Fisk, Black and Brunner, 2012; Bluyssen, 2019). Allergy symptoms, asthma and Sick Building Syndrome (SBS) are among the more critical health problems recorded (Silva et al., 2017).

Numerous studies have shown that natural light in office spaces improves worker satisfaction and productivity; the Flourish Model focuses on the daylight factor as part of the lighting environment because, as mentioned previously, humans spend 80 to 90 per cent of their time indoors. It's more important than ever to make sure natural light is available for everyone within an office environment, this can be explained by the literature of (Beute and de Kort, 2018, (Li and Lam, 2001; Li, 2010; Beute and de Kort, 2018, Mansfield, 2018). The absence of daylight affects the occupants' health and wellbeing; it is recommended that providing excellent color is the optimal light source for visual comfort and human health.

The acoustics are also crucial for the noise from its different resources. The Flourish Model highlighted that the open plan office noise might negatively impact employees' fatigue, performance, and motivation (Jahncke and Halin, 2012, Clements-Croome, Turner and Polaris, 2019. Finally, the layout has ample attention as part of the subjective parameters, and it mainly concerns the spaces and the functionality, as supported by (Haynes 2008; Lee, 2010).

Figure 2 about here

It was relevant to understand how the IEQ factors and sub-factors affected the doctoral and post-doctoral researchers in five research rooms at Brunel University, with the same outdoor environment, but different indoor environments. The chosen research rooms are used by Brunel Design School in Michael Sterling Building, the accounting department in the Eastern Gateway Building, the Computer Science department in Wilfried Brown building, the Economic department in Marie Jahoda Building and the Civil Engineering department in Howell Building.

The survey instrument (shown in Appendix 1) addressed the five facets of the IEQ aspects that most affect each occupant's health, well-being and productivity in the workplace, among a broad selection of questions constructed based on the IEQ across their workplaces: The information from the survey consisted of:

1. Background information
2. Post-occupancy evaluation for the workplace was conducted to show which IEQ factors affected occupants' health and well-being the most. The questions were based on the sub-factors used in the Flourish Model.
3. The relation between the IEQ factors and the occupants' productivity.
4. The potential for adding Biophilic design patterns to resolve the IEQ issues in the workplace.

The results are entirely based on those completed questions deemed appropriate for analysis. The coding phase involved assigning binary variables to the user responses in the SPSS data file. Moreover, the quantitative survey scale grading is divided into seven satisfying levels from strongly disagree (1) to strongly agree (7) to follow the Flourish Wheel rating method, which includes a moderate or neutral midpoint, and 7-point scales are known to be the most accurate scales as it relates to an agreement that would be distinct enough for the respondents, without throwing them into confusion.

The results have been presented on three levels; the first one is a qualitatively descriptive analysis of the occupants' satisfaction as well as their health and well-being in each one of the five offices, as in Table 3 below;

Table 3 about here

Then there's the second level of the analysis which quantitatively measures the occupants' productivity in each one of the rooms based on four variables that best contribute to human productivity. These variables were personal control, responsiveness, building depth, and workgroups.

And finally, the third level of the results shows the correlation analysis to improve the study rooms using the Biophilic patterns.

As for the survey sampling, for tiny populations ($n < 100$), there's a need for almost the entire population to achieve accuracy. There is a limit on the accuracy you can achieve when dealing with small sample. Therefore, the research sample size for this study is set out as Table 4, since the Confidence Level is 95%, and the Margin of Error is 5%.

Table 4 about here

3. Overview of IEQ in Brunel University’s research rooms

This study was conducted at Brunel University London in wintertime; it is located in the Uxbridge area of London, England. The study evaluated the IEQ factors of the research rooms in five buildings, each of which has a number of multi-disciplinary occupants, varies in size, methods of ventilation (including different types of windows), mode of thermostatic control and level of use of electrical equipment.

The first office was the doctoral and post-doctoral researchers’ room in the Michael Sterling building (Figure 3). It is an open-plan office consisting of 15 occupied desks. It has two doors (the main entrance and an emergency exit) and an elevation with large windows giving direct access to the outside environment.

Figure 3 about here

The Howell Building (Figure 4) housed the second post-graduate room selected. This open-plan office can accommodate 20 doctoral and post-doctoral researchers. It has two doors but no windows; in particular, it has no access to fresh air, it is the oldest building in the university.

Figure 4 about here

The third workplace was located in Marie Jahoda building which is one of its old buildings in the university. Its small open-plan research room has two windows and one main door.

Figure 5 about here

Wilfried Brown building which include the Stem Centre, and it is where the computer science department is located, was the fourth building in the study to be considered. It is one of the newest buildings on campus. Many forms of technology have been incorporated into this building, including photovoltaic panels, temperature regulation systems and rainwater harvesting. The room for the computer science department is occupied by 15 doctoral and post-doctoral researchers and is open plan in type. It has two doors and large windows along the elevation, constructed of glass.

Figure 6 about here

the Eastern Gateway Building is last considered building which is rated BREEAM Excellent. This building was planned, built, and occupied to ensure the most significant efficiency in energy and water use and the lowest carbon emissions possible. It uses natural ventilation for cooling and has reduced glazed areas to minimize solar gain. It also uses some renewable energy technologies.

Figure 7 about here

3.1. IEQ Factors and Sub-Factors

The sub-factors for the IEQ in the office building were chosen based on the Flourish Wheel design. It was clear that the objective parameters are primarily related to IEQ aspects (Table 5), while the subjective parameters (Table 6) correspond to the space's layout and aesthetic values.

Table 5 about here

Table 6 about here

3.2. Descriptive analysis

The first set of analyses examined the users' satisfaction in the research room with each of the IEQ sub-factors and discussed how their health and well-being were used.

The respondents were asked about their satisfaction with two main sub-factors, temperature and humidity, starting with the thermal environment. The results are set out in Table 7. As can be seen, the respondents in the Michael Sterling building (panel A of Table 7) and the Eastern Gateway Building (panel B of Table 7) are partially agreed about their satisfaction with the temperature and humidity levels in the office; the means in both cases are around 5 (Slightly Agree) out of 7 (Strongly Agree).

This result explains natural ventilation to cool buildings, reduced glazed areas, and orientating structures to minimise solar gain. However, the lack of a tool, a suitable kind of plant that could balance the humidity inside the office or even the HVAC system is how this space could be improved to satisfy the researchers' preferences about thermal comfort.

Table 7 about here

For the Marie Jahoda Building and the Howell Building, it can be seen from the data in panel C panels of Table 8 that the researchers disagreed that their office temperature (Mean= 2.27 and Mean=2.52) and humidity (Mean=2.45 and Mean=1.60) levels suited their preferences. There are several possible explanations for this result. One is that these are among the university's oldest buildings. They were constructed of red brick, the windows were tiny, and the offices had an open-plan layout but still felt crowded. The researchers agreed that such an environment had a slightly negative effect on their health. Similarly, the participants who worked in the Stem Centre were not satisfied with either the temperature or the humidity because the glass used to construct the front elevation of the building allowed too much sunshine in summer to access the room; it unbalanced the indoor temperature and gave no shade.

Graphical information on the location, the dispersion and the skewness of a data set for which summary measures were introduced in Table 6 can be seen in Figure 8 and Figure 9. As for Figure 8, it is apparent that the median of respondents' temperature satisfaction who used the Howell building is the greatest among the considered research rooms followed by those who used to be in the Michel sterling room. The picture almost not changed in Figure 9 where respondents' Humidity satisfaction in the Michel sterling and Howell building is the largest among others.

Together, the results shown in those figures highlighted that the interquartile ranges are reasonably similar (as shown by the lengths of the boxes).

Figure 8 about here

Figure 9 about here

The second group of questions related to indoor air quality. The researchers were asked about the freshness of the air in their offices, how polluted it was, if the window arrangements helped to improve the air quality, and if their offices had any green features that could freshen the room's air respondents in the Michael Sterling building (panel A of Table 8), the Eastern Gateway Building (panel B of Table 8) and at the Stem Centre (panel E of Table 8), are agreed that their office admits fresh air through the windows. Still, they disagreed on whether it was occasionally polluted. However, the respondents strongly agreed that their office lacked green plants that would help to provide fresh air in the office. Some respondents also agreed that they experienced some annoying symptoms from the air conditions such as headache, dry eyes, coughs, sputum, itching nose and dry skin. The others, however, responded that the air quality in the office did not affect their health either positively or negatively.

The researchers in the sample who worked in the older premises such as the Marie Jahoda Building and the Howell Building (panels C and D of Table 8) disagreed that there were enough windows to control the variable airflow in the space, and no plants or green features in the office, which slightly affected their health and well-being (Mean=3.18).

Table 8 about here

The information introduced in Table (8) is represented graphically as shown in Figures (10) and (11). These Figures complement each other in which those who satisfied with the degree of fresh air in the building (as in Michel Sterling and Stem Centre) are less annoyed by the pollution degree inside these rooms compared with those who use other buildings.

Again, the results shown in those figures highlighted that the interquartile ranges are reasonably similar (as shown by the lengths of the boxes).

Figure 10 about here

Figure 11 about here

The purpose of the third set of questions was to examine the respondents' satisfaction with the noise level in their office and the acoustic environment. Out of the five considered buildings, only the researchers in the Michael Sterling building (see Panel A of Table 9) and the Stem Centre (presented in Panel E of Table 9) agreed that they were satisfied with the acoustic levels in their room; the only source of noise for them came from the traffic outdoors. As a result, they agreed that their hearing, health and well-being were unaffected. The only type of noise in the office, according to the participants, was the conversations around them because of the open-plan spatial layout of the office.

Table 9 about here

As for the rest of our sample, the researchers slightly disagreed with their satisfaction with the noise level in their office. They reported that they were always aware of both telephone and other conversations and noise from the heating, ventilation, air conditioning (HVAC) and machines. The results also show that this noise level hurts the quality of their hearing and increases stress, which negatively affects their productivity.

In Figure 12 these facts are presented in which the similarity among the respondents are evidenced as shown by the lengths of the boxes. With the exception of Michael Sterling in which the respondent's show more scattered data (Larger ranges indicate wider distribution).

Figure 12 about here

Fourth, when asked about the lighting environment, the researchers were invited if their office had enough access to daylight. The results in Table (10) show that they agreed that the new buildings, including the Michael Sterling building (Panel A of Table 10), the Eastern Gateway Building (panel B of Table 10) and at Stem Centre (Panel E of Table 10) have good access to daylight through the windows. However, they disagreed that the light in their offices negatively affects the health of their vision. A possible reason is the use of intelligent fluorescent and LED lighting in many building areas; high-efficiency light fittings and LED lighting have movement sensors to detect when people are present and switch off lighting at other times.

Table 10 about here

Regarding the Howell and Marie Jahoda buildings, the researchers highlight that their rooms had no adequate openings or windows; this prevented the access of daylight, which in turn had a bad environmental influence on the occupants' health and well-being. The results in panels B and C of Table 10 also show that the researchers strongly agreed that constant working in artificial light negatively affects their vision, which affects their productivity. These facts are explained in Figure (13). It is worth noting that in Figure 15 the respondents in Howell building have the most dispersed answer as shown by the longer box.

Figure 13 about here

Finally, the researchers were asked about their satisfaction with the general layout of their office and its orientation, the space between the desks, and the neighbourhood design's effect on the office in specific. The results show that those researchers from the Michael Sterling building (shown in Panel A of Table 11) as well as those who used the offices in the Stem Centre were satisfied with the orientation of the office and with the space between all the desks but had slight reservations about the design of the neighbourhood: their office had some views of greenery but not enough to make them feel comfortable.

Table 11 about here

Graphical information of a data set for which summary measures were introduced in Table 11 can be seen in Figure (14) and Figure (15).

Figure 14 about here

Figure 15 about here

4. The direct impact of the IEQ factors on productivity

In this stage of the research, it was essential to evaluate perceived productivity in each office. This regression analysis would link the respondents' satisfaction with each IEQ factor with the researchers' perceived productivity factors as dependent variables. It is worth noting that, among others, Leaman & Bordass, who are members of the United Kingdom's (Usable Buildings Trust), listed what variables best contribute to human productivity. These variables were personal control, responsiveness, building depth, and workgroups. Personal management refers to the level of comfort experienced by individuals in their workplaces, which pertains to "heating, cooling, lighting, ventilation and noise". Responsiveness refers to the ability of a workplace environment to adapt to changes in employee needs. Building depth is its capacity to provide appropriate levels of natural ventilation, air conditioning and window arrangements. The variable of workgroups refers to the sheer size of groups working together in a workplace. Research suggests a delicate balance must be achieved between solitary individuals and large groups working together in an open environment (Leaman and Bordass, 1999).

Below, we present regression analysis models investigating how the listed variables contribute to human productivity. Starting with the impact of the IEQ factors on the rooms to adapt to changes can be written as

$$Personal\ Control = \alpha_1 Thermal + \alpha_2\ Air\ Quality + \alpha_3\ Acoustic + \alpha_4\ Lighting + \alpha_5\ Layout \qquad (1)$$

Next in equation 2, the impact of the considered factors on the responsiveness can be expressed as

$$Personal\ Control = \beta_1 Thermal + \beta_2\ Air\ Quality + \beta_3\ Acoustic + \beta_4\ Lighting + \beta_5\ Layout \qquad (2)$$

As for the effects of the IEQ on the building depth, the regression line can be estimated through equation three below

$$building\ depth = \gamma_1 Thermal + \gamma_2\ Air\ Quality + \gamma_3\ Acoustic + \gamma_4\ Lighting + \gamma_5\ Layout \qquad (3)$$

Last, the impact of the IEQ on Workgroups can be expressed as

$$Workgroups\ = \delta_1 Thermal + \delta_2\ Air\ Quality + \delta_3\ Acoustic + \delta_4\ Lighting + \delta_5\ Layout \qquad (4)$$

It is worth mentioning that the vectors of parameter $\alpha_i, \beta_i, \gamma_i, \delta_i$ need to be estimated.

The results of the multiple analyses for the five buildings are summarised below. With the comfort level as the dependent variable, the overall model was statistically significant at $\rho < 0.05$, as suggested through the F-value. The proportion of variance explained by these regressors in the model is reasonably informative (see panel B of Table 12 for the values of R^2). Furthermore, no serial correlation is found since the DW statistics are close to 2.

Furthermore, the model indicates that the results varied from one building to another. In specific, the results of the regression analysis show that almost all the IEQ factors in both Eastern Gateway and the Stem Centre have a significant positive impact on the rooms to adapt to changes. The same can be seen in the Michael Sterling building. A significant positive effect of the regressors is found except in the case of thermal comfort, which had a significant negative impact. The latter indicates that the unstable thermal environment affected the researchers' productivity in the office.

It is also apparent from this table that air quality, thermal comfort and lighting negatively affected the productivity of the Howell Building occupants. However, both the acoustics and layout had an insignificant effect. This also applies to the researchers accommodated in Marie Jahoda, where most variables had no impact, except for the indoor air quality and layout, which had a significant negative effect.

Table 12 about here

Next came the question of Responsiveness to the IEQ factors. Table 13 highlights that the overall model was statistically significant at $\rho < 0.05$ since the F-value is greater than 1. Further, the proportion of variance explained by these regressors in the model is relatively high, as suggested by the R^2. Again, no serial correlation is found since the DW statistics are close to 2.

A closer inspection of the table also shows that in the Michael Sterling building, with the dependent variable of responsiveness, all the variables considered positively affect the users' productivity. The results in the case of Eastern Gateway and the Stem Centre show evidence of a significant positive impact from all the variables except the acoustic comfort, which has a significant negative effect. A possible reason for this is that the building was new and could be improved to increase the users' productivity. Acoustic comfort was the most negative effect on their productivity.

By contrast, all the variables hurt the productivity of researchers at both the Howell and Marie Jahoda buildings. Specifically, the occupants emphasised that all the IEQ factors negatively affected their comfort level, which directly affected their health, well-being, and productivity.

Table 13 about here

The third set of analyses examined the impact of the role of IEQ factors on the researchers' productivity when the building depth was the dependent variable. As presented in Table 14, the estimated model was statistically significant for each building. Moreover, the proportion of variance explained by these regressors in the model is quite acceptable, as suggested by R^2. Furthermore, the model is well specified since no evidence of serial correlation is found (DW is close to 2).

Regarding the estimated coefficient, the air quality and thermal comfort significantly imp the users' productivity of such relatively new buildings as Eastern Gateway and the Stem Centre, but the other factors have no effect. However, the case of the Michael Sterling building indicates a significant positive impact on the air quality variable and an insignificant one for the other variables. The reason is that potential of this office to affect the level of natural ventilation, the air conditioning and the window arrangements negatively affects workers' health, well-being and productivity.

For both Howell and the Marie Jahoda buildings, the researchers were sure that the office's capacity to affect the level of natural ventilation, the air conditioning, and the window arrangements is negatively affected by air quality and thermal comfort factors.

Table 14 about here

The subsequent regression analysis involves the impact of IEQ on productivity using workgroups as the dependent variable. As shown in Table 15, the variables in question are jointly significant at $\alpha < 0.05$. Further, these estimators explain a reasonable amount of the variation in the dependent variable, as indicated by R^2. Furthermore, no serial correlation is found since the DW statistics are close to 2.

The model indicates the significant positive impact of almost all the variables on productivity in the case of the Michael Sterling, Stem Centre and Eastern Gateway buildings (except for thermal comfort in the Stem Centre, which has an insignificant impact. That is to say; the researchers agree that their overall satisfaction had positively affected their productivity in their office environment. But, in line with the descriptive analysis, it was clear that all the researchers were dissatisfied with their office environment in the Howell and the Marie Jahoda buildings.

Table 15 about here

5. The role of Biophilic Design patterns in improving conditions in the indoor workplace

Correlation analysis was used to explore the possibility of improving the indoor workplace environment by using the patterns of the Biophilic Design; the survey questions included questions about adding natural features, presence of green elements and plants, daylight, controlling Indoor air quality and thermal comfort, noise, size and orientation of the windows, view, the existence of water and many more.

The correlation analysis involved measuring the relationship or correlation between two sets of variables: the IEQ factors and the Biophilic Design applications in the workplace, in order to ascertain whether they were positively or negatively related, or not associated in any way whatsoever. Put differently, the researchers were asked seven categories of questions regarding the potential of applying Biophilic Design to improve their workplace, the possibility of using Biophilic applications to solve the problems with the five main IEQ factors, as well as three additional categories. These categories are the aesthetic values that Biophilic Design adds to a building, the potential to apply Biophilic Design to balance the adverse IEQ factors in the office environment, and the effect on the researchers' health, well-being and productivity of adding Biophilic applications.

Table 16 shows the correlation analysis which expresses the degree of the association or the relationship. In the Michael Sterling building and the Stem Centre, there is clear evidence that participants highlighted the need to improve the aesthetic values and thermal comfort, one of the variables positively correlated with the researchers' wellness.

For those in the Eastern Gateway buildings, it is clear that the highest correlation was for other Biophilic applications to balance the IEQ levels. Next came the aesthetic additions of Biophilic design aspects that were mostly connected with their wellness. Moreover, the researchers were sure that the acoustics environment of their office needed improvement.

The case with the older buildings (the Marie Jahoda and Howell Buildings) was found to be somewhat different. The researchers in the former building paid more attention to the quality of the air indoors, followed by the Biophilic applications of the lighting environment that mainly were connected with their wellness. Moreover, the layout was one of the essential variables that would enhance their wellness if it was improved using Biophilic Design patterns. Similarly, for the Howell building, the correlation between indoor air quality and wellness was the highest, followed by Biophilic patterns applied to the lighting environment. The need to add aesthetic plants and greenery as well as HVAC systems was another of the variables that are positively correlated with the researchers' wellness.

Table 16 about here

6. Conclusion

This paper surveyed the relationship between the indoor environmental quality (IEQ) – factors and sub-factors – and the occupants' health, well-being and productivity, based on the Flourish Wheel in the open-plan research offices at Brunel University London.

The most prominent finding to emerge from this study is that the qualities of the five key IEQ aspects, namely, thermal comfort, indoor air quality, lighting environment, acoustic environment and the office spatial layout, have significantly positive correlations with the occupants' wellness.

The second significant finding was that of the five critical aspects of IEQ, the quality of the thermal environment and the indoor air quality have the most important influence on productivity in the older buildings due to the lack of fresh air as well as the precarious balance in the levels of temperature and humidity. However, the descriptive analysis shows that the new buildings' occupants were satisfied with thermal comfort, indoor air quality, and lighting, though they had some reservations regarding the office layout and acoustic comfort. Such matters are always possible and even expected in open-plan offices.

One of the more significant findings to emerge from this study is from the regression analysis, which shows that the level of comfort that individuals experience within their workplace environments was satisfactory in the Eastern Gateway building, the Stem Centre and the Michael Sterling building. It had a direct positive effect on the productivity there.

Overall, this study strengthens the idea that the IEQ Issues appeared in the 5 research rooms can be improved using different methods including the Biophilia. As a first solution for the rooms generally, Applying HVAC (heating, ventilation and air conditioning) delivery combined with natural plant strategy is going to impact positively on the occupants' satisfaction.

As for the thermal comfort issues this can be enhanced generally by applying plants that are responsible for converting carbon dioxide to oxygen specifically at night, in addition to some kind of Green walls that absorb heat, humidity & moisture imbalances. In Marie Jahoda building, and because of the small windows, applying window planters, and use the kind of plants that give an excellent ability to filter VOC's from the air, can help with the Indoor air quality issues.

Lastly, lighting problems can be avoided by using blinds that cut out to project shadows and light, also to control the sun direction to the inside as in both stem center and the eastern gateway. Using Partitions, or moving some existing furniture and plants can be part of solving acoustics and layout problems by creating private spaces for retreating & restoring energy.

This study is part of a small body of literature; therefore, the ideas proposed in this study, as well as the findings, could be valuable for both academic and design practitioners. Further work needs to be done to establish a co-design toolkit that helps designers and architects to improving open-plan workspaces using the patterns of Biophilic Design by evaluating the main IEQ factors and making aesthetic additions where possible.

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Table1 : The most recent POE models

Model	MASLOW	PERMA	SALIENCE	BALANCED	FLOURISH
Author	Maslow	Seligman	Dolan	Lily Berheimer	Clements-Croome
Year	1943	2011	2016	2017	2016/2018
Evaluation Factors	Self-Actualisation	Positive emotion	Sound	Biophilia-material, views and patterns	Subjective Design Parameters: Space, Layout and functionality, Character, Colour, Aesthetics, Views, Greenery/Nature,
	Esteem	Engagement	Air	Atmospheric light, air quality, temperature and smell	Objective Design Parameters: Daylight, Air Quality, Noise, Pollution, Temperature, Dampness.
	Social	Positive relationships	Light	Layout-space quality, circulation	Perceptual Impact: Health and Wellbeing, Happiness and satisfaction, decreased stress, empowerment and achievement, safety and security, personal relationship, community.
	Safety	Meaning	Image	Amenities - nutrition, movement, ergonomics	Economic Impact: decreased public spending, increased asset value, higher rental rates, productivity and performance, absenteeism and presenteeism, prosperity and social capital.
	Physiological	Accomplishment/ achievement	Ergonomics	Noise	
			Nature	Cohesion – community, communication	
			Colour	Energy-resources and waste	
				Design-Colour, shape, materials, proportions, detail and style	

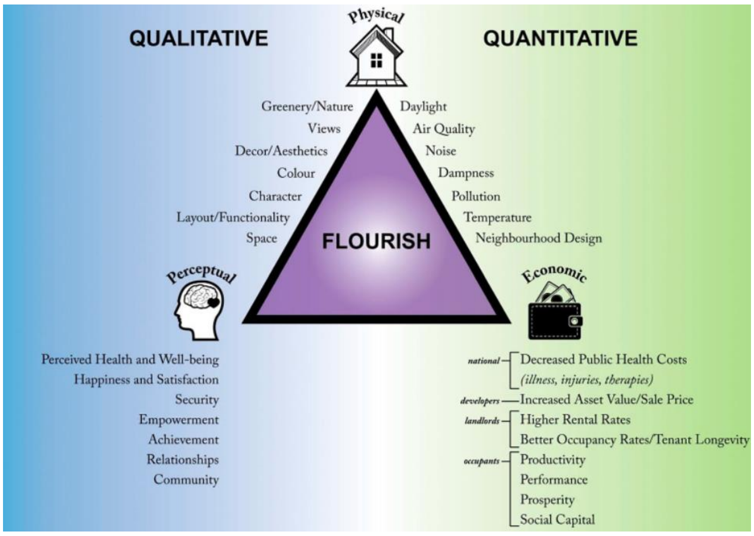


Figure 1: The Flourish Model

Table 2 the link between the patterns of Biophilia and the IEQ factors and sub-factors

IEQ Factors and Sub-factors		Biophilia Patterns	Reference
Thermal comfort	Temperature Humidity	- Non-Visual Connection with Nature (Pattern 2) - Thermal & Airflow Variability (Pattern 4) - Connection with Natural Systems (Pattern 7)	- Berman, M.G.; Jonides, J.; Kaplan, S. The cognitive benefits of interacting with nature. J. Psychol. Sci. 2008, 19, 1207–1212. [CrossRef] - Windhorst, E.; Williams, A. "It's like a different world": Natural places, post-secondary students, and mental health. Heal. Place 2015, 34, 241–250. [CrossRef] [PubMed] - Stigsdotter, U.K.; Corazon, S.S.; Sidenius, U.; Refshauge, A.D.; Grahn, P. Forest design for mental health promotion—Using perceived sensory dimensions to elicit restorative responses. Landsc. Urban Plan. 2017, 160, 1–15. [CrossRef] - Shi, S.; Man, Y.; Wang, Z.; Wang, L.; Zhang, X. On site measurement and analysis on indoor air environment of classroom in university campus. Procedia Eng. 2017, 205, 2200–2207. [CrossRef]
Indoor Air Quality	Fresh air quality Polluted Air Greenery and nature	- Visual Connection with Nature (Pattern 1) - Non-Visual Connection with Nature (Pattern 2) - Non-Rhythmic Sensory Stimuli (Pattern 3) - Connection with Natural Systems (Pattern 7)	- Windhorst, E.; Williams, A. Bleeding at the roots: Post-secondary student mental health and nature affiliation. Can. Geogr. 2016, 60, 232–238. [CrossRef] Putri, N.T.; Amrina, E.; Nurnaeni, S. Students' perceptions of the implementation of sustainable campus development based on landscape concepts at Andalas University. Procedia Manuf. 2020, 43, 255–262. [CrossRef]

Acoustics	Noise	- Non-Rhythmic Sensory Stimuli (Pattern 3) - Non-Visual Connection with Nature (Pattern 2) - Visual Connection with Nature (Pattern 1)	- Jahncke, H.; Hygge, S.; Halin, N.; Green, A.M.; Dimberg, K. Open-plan office noise: Cognitive performance and restoration. J. Environ. Psychol. 2011, 31, 373–382. [CrossRef]
Lighting	Daylight	- Dynamic and Diffuse Light (Pattern 6) - Biomorphic Forms & Patterns (Pattern 8)	IESNA. The IESNA Lighting Handbook: Reference and Applicaltion; Illuminating Engineering Society of North America: New York, NY, USA, 2000. Karlen, M.; Benya, J.R. Lighting Design Basics; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2004.
Layout	Layout and functionality	- Dynamic and Diffuse Light (Pattern 6) - Non-Visual Connection with Nature (Pattern 2) - Biomorphic Forms & Patterns (Pattern 8) - Material Connection with Nature (Pattern 9) - Complexity and Order (Pattern 10) - Prospect (Pattern 11)	Bellia, L.; Pedace, A.; Barbato, G. Lighting in educational environments: An example of a complete analysis of the effects of daylight and electric light on occupants. Build. Environ. 2013, 68, 50–65. [CrossRef] Felsten, G. Where to take a study break on the college campus: An attention restoration theory perspective. J. Environ. Psychol. 2009, 29, 160–167. [CrossRef]
	Spaces		

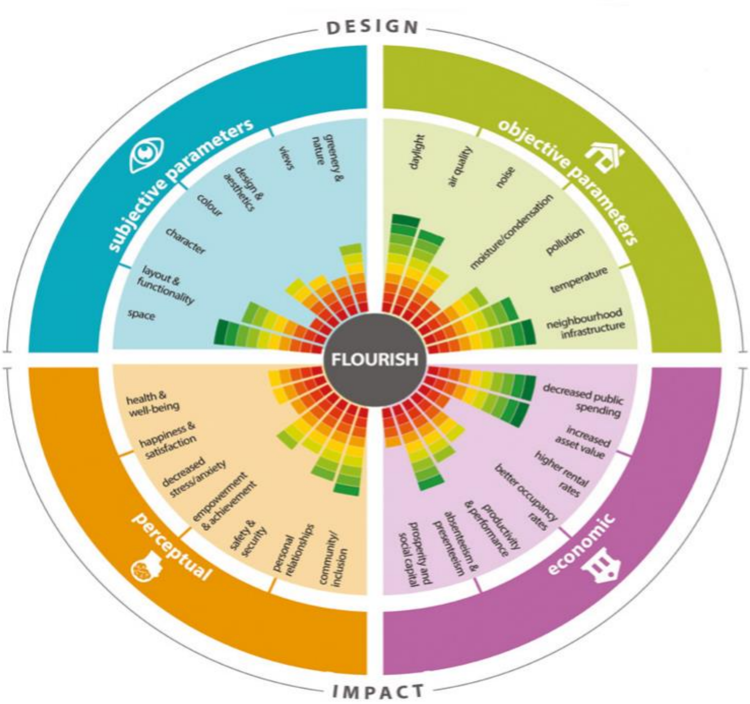


Figure 2 The Flourish Wheel

Table 3; Descriptive analysis

Descriptive analysis		Location
IEQ factors: **1.** Thermal comfort **2.** Indoor Air Quality **3.** Acoustics **4.** Lighting **5.** Layout	Indoor Environment Quality sub-factors	**For Each** one of the five offices
	Health and well-being	

Table 4; Sample size

Main Group	Sub-group	Number of the occupants in each room	Minimum Sample Size
Doctoral and Post-Doctoral Researchers workplaces	Michael Sterling	15	15
	Howell	20	20
	Marie Jahoda	11	11
	Eastern Gateway	20	20
	Stem Centre	15	15
Total:			81

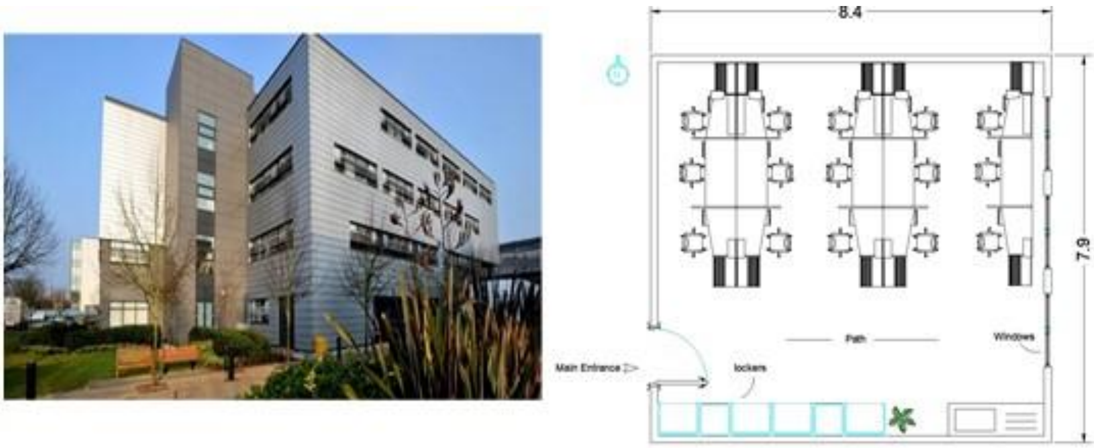


Figure 3 Michael Sterling building

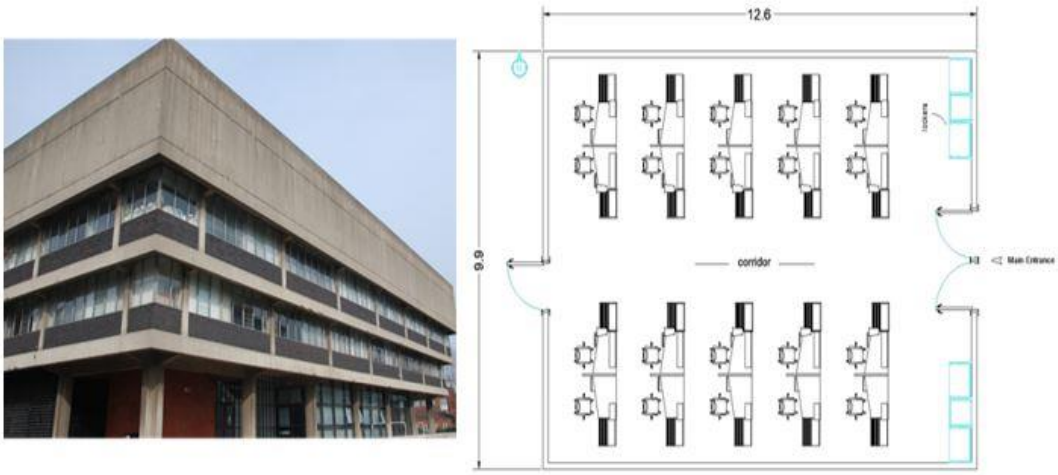


Figure 4 Howell Building

Figure 5 Marie Jahoda building

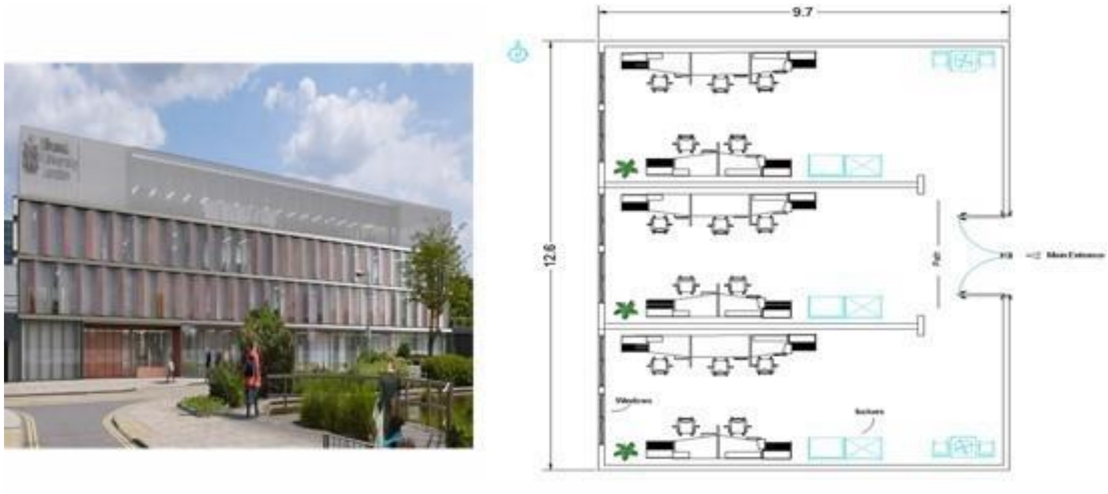


Figure 6 the Stem Centre

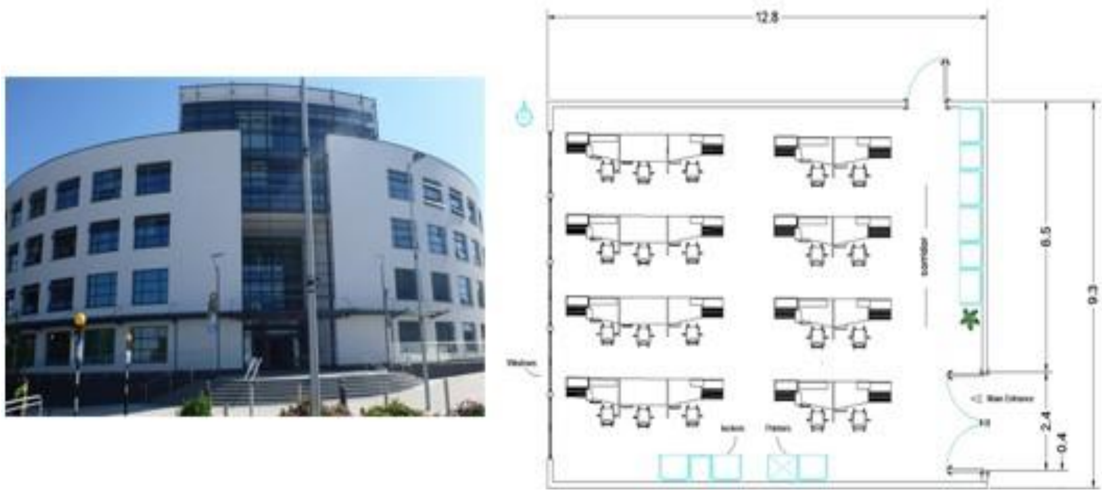


Figure 7 Eastern Gateway Building

Table 5: IEQ factors and subfactors according to the Flourish Wheel (objective parameters)

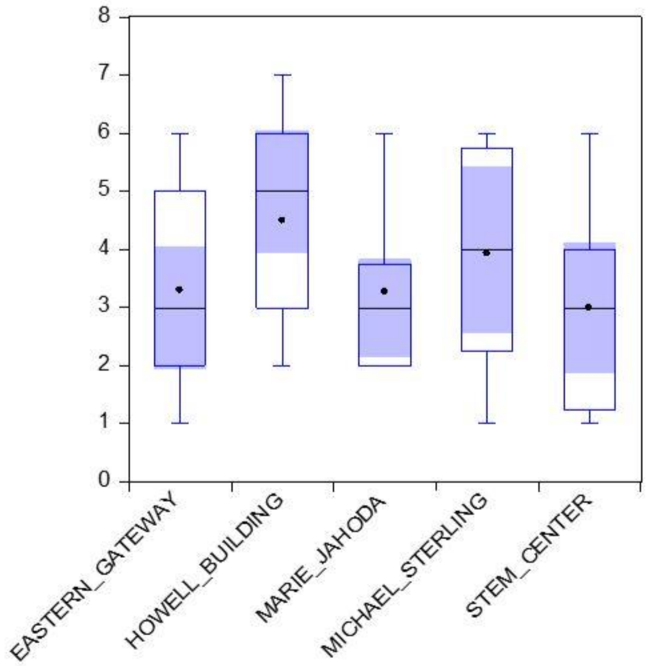
IEQ Factors	Objective Parameters (Design sub-factors)						
	a. Daylight	b. Air Quality	c. Noise	d. Dampness	e. Pollution	f. Temperature	g. Neighborhood infrastructure
1. Office layout							
2. Air quality		■			■		■
3. Thermal environment				■		■	
4. Lighting environment	■						
5. acoustic environment			■				■

Table 6: IEQ factors and subfactors according to the Flourish Wheel (Subjective parameters)

IEQ Factors	Subjective Parameters (Design sub-factors)						
	a. Space	b. Layout and functionality	c. Character	d. Color	e. Design and aesthetics	f. Views	g. Greenery and nature
1. Office layout	■	■					
Aesthetic Values (Indirect effect)			■	■	■	■	■

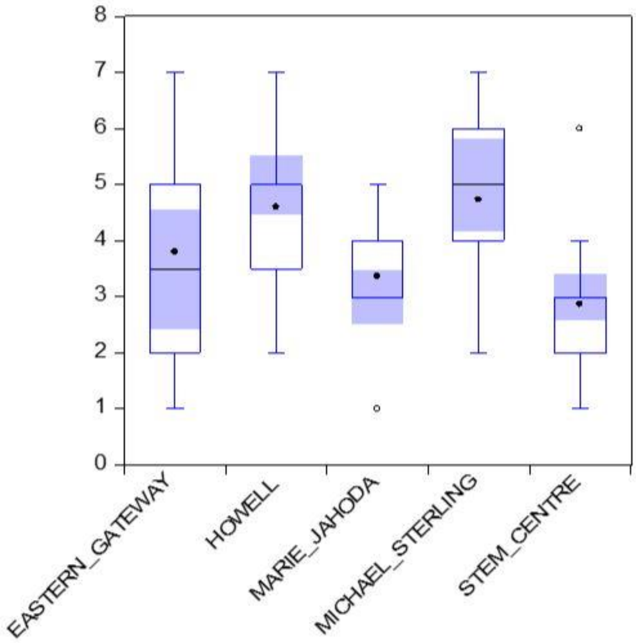
Table 7 Analysis of the thermal environment

	Temperature	Humidity	Health & Wellbeing
Panel A; Michael Sterling			
Mean	5.93	4.73	4.97
Std. Deviation	1.75	1.62	1.87
Variance	3.07	2.64	3.5
Panel B; Eastern Gateway			
Mean	5.3	5.8	1.7
Std. Deviation	1.42	1.79	1.22
Variance	2.01	3.22	1.48
Panel C; Marie Jahoda			
Mean	2.27	2.45	3.64
Std. Deviation	1.49	0.93	1.43
Variance	2.22	0.87	2.06
Panel D; Howell			
Mean	2.52	1.6	3.2
Std. Deviation	1.61	1.35	1.44
Variance	2.58	1.83	2.06
Panel E; Stem Centre			
Mean	2	2.87	2.13
Std. Deviation	1.73	1.51	1.68
Variance	3	2.27	2.84



x-axis illustrates the research rooms under consideration, while the y-axis is the quantitative survey scale ranging from strongly disagree (1) to strongly agree (7). The whiskers represent the ranges for the bottom 25% and the top 25% of the data values, excluding outliers. The black denotes the mean where the dash represent the median of the sample.

Figure 8 Box Plot of Respondents' Temperature Satisfaction (As Presented in Table 7)

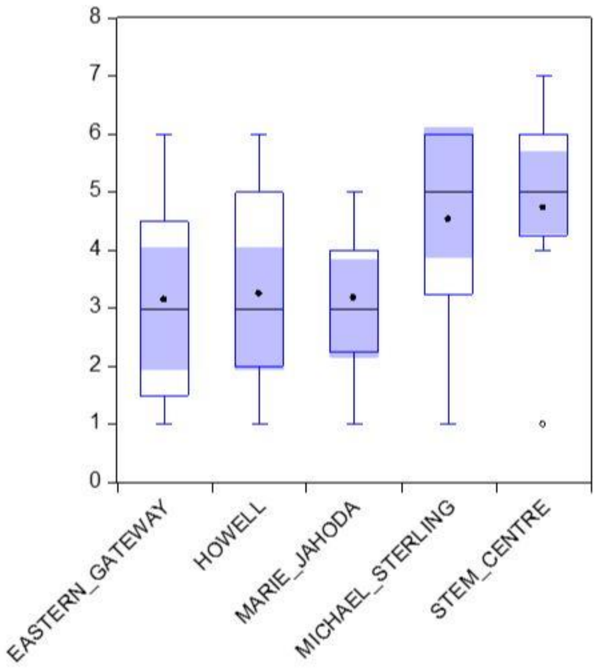


x-axis illustrates the research rooms under consideration, while the y-axis is the quantitative survey scale ranging from strongly disagree (1) to strongly agree (7). The whiskers represent the ranges for the bottom 25% and the top 25% of the data values, excluding outliers. The black denotes the mean where the dash represent the median of the sample.

Figure 9 Box Plot of Respondents' Humidity Satisfaction (As Presented in Table7)

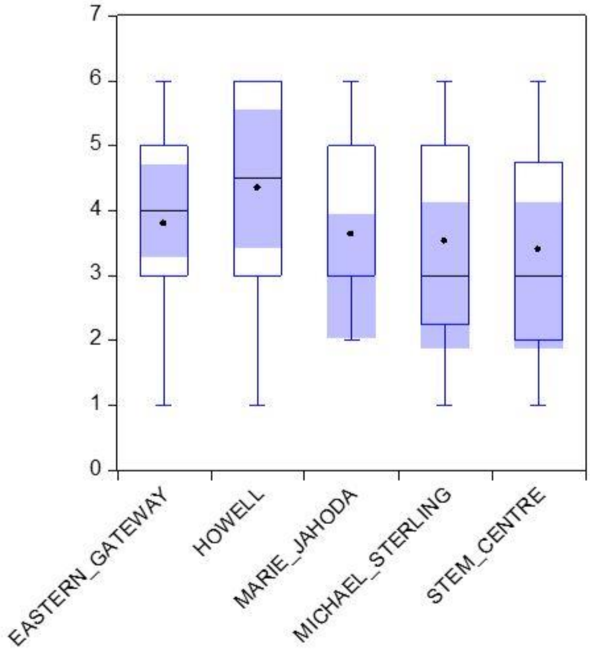
Table 8 The indoor air quality

	Fresh	Polluted	Health and Wellbeing
Panel A; Michael Sterling			
Mean	5.53	2.53	4.4
Std. Deviation	1.77	1.6	1.59
Variance	3.12	2.55	2.54
Panel B; Eastern Gateway			
Mean	5.15	1.8	2.3
Std. Deviation	1.79	1.4	1.98
Variance	3.19	1.96	3.91
Panel C; Marie Jahoda			
Mean	2.27	3.82	3.18
Std. Deviation	1.35	1.25	1.17
Variance	1.82	1.56	1.36
Panel D; Howell			
Mean	2.25	4.78	4.95
Std. Deviation	1.68	1.69	1.61
Variance	2.83	2.87	2.58
Panel E; Stem Centre			
Mean	5.73	5.4	2.13
Std. Deviation	1.71	1.55	1.19
Variance	2.92	2.4	1.41



x-axis illustrates the research rooms under consideration, while the y-axis is the quantitative survey scale ranging from strongly disagree (1) to strongly agree (7). The whiskers represent the ranges for the bottom 25% and the top 25% of the data values, excluding outliers. The black denotes the mean where the dash represent the median of the sample.

Figure 10 Box Plot of Respondents' Fresh Air Satisfaction (As Presented in Table 8)

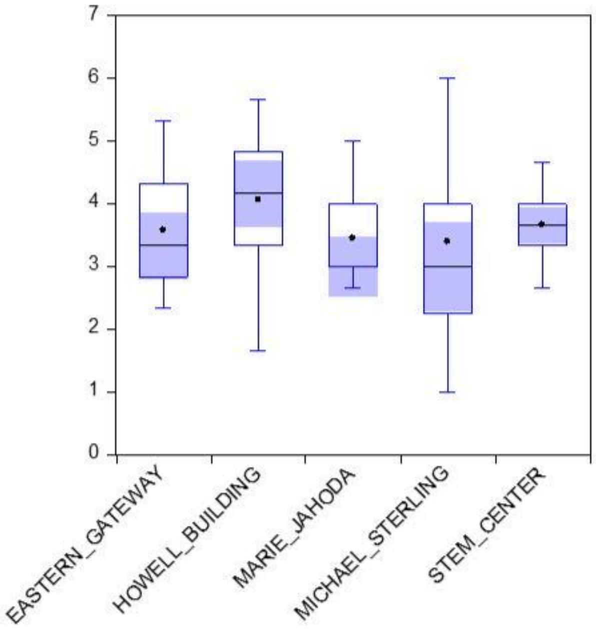


x-axis illustrates the research rooms under consideration, while the y-axis is the quantitative survey scale ranging from strongly disagree (1) to strongly agree (7). The whiskers represent the ranges for the bottom 25% and the top 25% of the data values, excluding outliers. The black denotes the mean where the dash represent the median of the sample.

Figure 11 Box Plot of Respondents' Polluted Air Satisfaction (As Presented in Table 8)

Table 9 Acoustic Comfort

	Noise	Health and Wellbeing
Panel A; Michael Sterling		
Mean	5.27	2.67
Std. Deviation	1.18	1.76
Variance	1.39	3.1
Panel B; Eastern Gateway		
Mean	2.58	4.15
Std. Deviation	0.9	1.39
Variance	0.82	1.92
Panel C; Marie Jahoda		
Mean	2.36	5.73
Std. Deviation	0.92	1.62
Variance	0.85	2.62
Panel D; Howell Building		
Mean	3.07	4.55
Std. Deviation	0.94	1.82
Variance	0.88	3.31
Panel E; Stem Center		
Mean	5.67	1.87
Std. Deviation	0.58	1.46
Variance	0.33	2.12

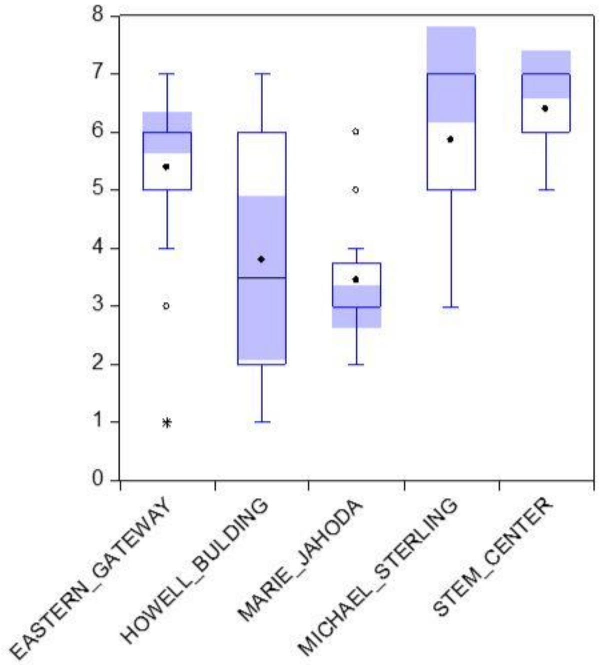


x-axis illustrates the research rooms under consideration, while the y-axis is the quantitative survey scale ranging from strongly disagree (1) to strongly agree (7). The whiskers represent the ranges for the bottom 25% and the top 25% of the data values, excluding outliers. The black denotes the mean where the dash represent the median of the sample.

Figure 12 Box Plot of Respondents' Polluted Air Satisfaction (As Presented in Table 9)

Table 10 Lighting Environment

	Daylight	Health & Wellbeing
Michael Sterling		
Mean	5.87	1.33
Std. Deviation	1.51	1.91
Variance	2.27	3.67
Eastern Gateway		
Mean	5.4	4.7
Std. Deviation	1.57	1.72
Variance	2.46	2.95
Marie Jahoda		
Mean	2.36	5
Std. Deviation	1.03	1.41
Variance	1.06	2
Howell		
Mean	1.8	3.15
Std. Deviation	1.91	1.98
Variance	3.64	3.92
Stem Center		
Mean	6.4	2.93
Std. Deviation	0.74	1.87
Variance	0.54	3.5

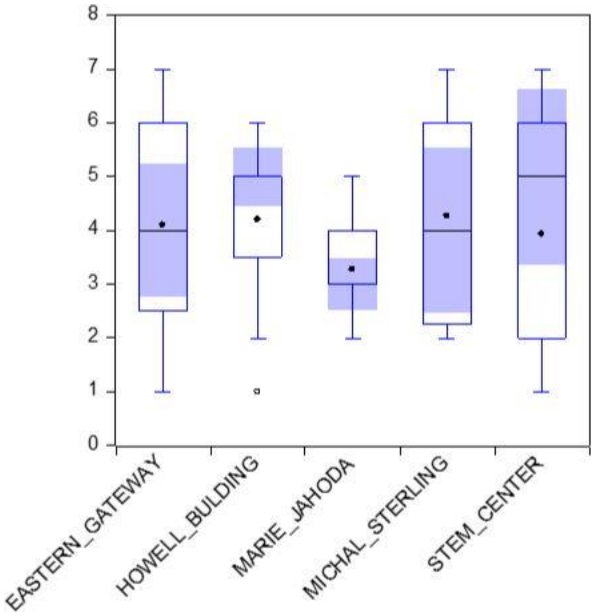


x-axis illustrates the research rooms under consideration, while the y-axis is the quantitative survey scale ranging from strongly disagree (1) to strongly agree (7). The whiskers represent the ranges for the bottom 25% and the top 25% of the data values, excluding outliers. The black denotes the mean where the dash represent the median of the sample.

Figure 13 Box Plot of Respondents' Daylight Satisfaction (As Presented in Table 10)

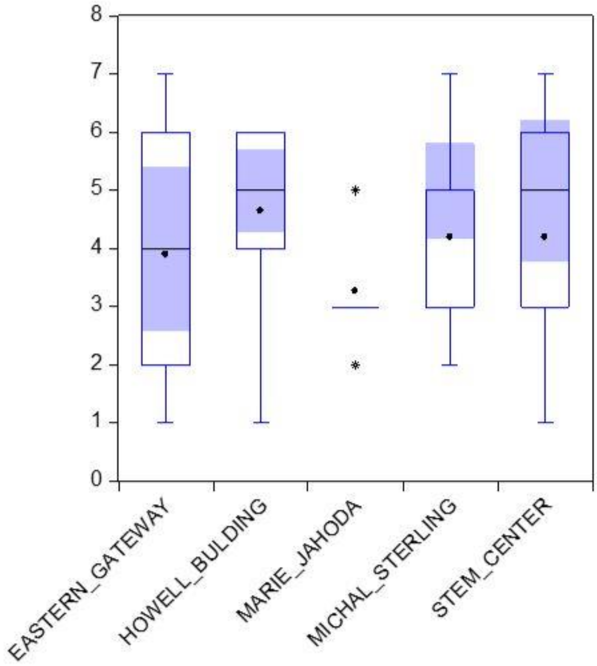
Table 11 Layout

	Layout and functionality	Spaces	Health & Wellbeing
Michal Sterling			
Mean	5.27	5.2	4.07
Std. Deviation	1.98	1.74	1.39
Variance	3.92	3.03	1.92
Eastern Gateway			
Mean	3.8	4.1	3.75
Std. Deviation	1.79	1.97	1.92
Variance	3.22	3.88	3.67
Marie Jahoda			
Mean	2.18	2.36	2.45
Std. Deviation	0.87	0.92	0.93
Variance	0.76	0.86	0.87
Howell			
Mean	3.2	3.65	3.35
Std. Deviation	1.67	1.42	1.69
Variance	2.8	2.03	2.87
Stem Center			
Mean	4.93	4.2	4
Std. Deviation	2.15	2.14	2
Variance	4.64	4.6	4



x-axis illustrates the research rooms under consideration, while the y-axis is the quantitative survey scale ranging from strongly disagree (1) to strongly agree (7). The whiskers represent the ranges for the bottom 25% and the top 25% of the data values, excluding outliers. The black denotes the mean where the dash represent the median of the sample.

Figure 14 Box Plot of Respondents' Layout and functionality Satisfaction (As Presented in Table 11)



x-axis illustrates the research rooms under consideration, while the y-axis is the quantitative survey scale ranging from strongly disagree (1) to strongly agree (7). The whiskers represent the ranges for the bottom 25% and the top 25% of the data values, excluding outliers. The black denotes the mean where the dash represent the median of the sample.

Figure15 Box Plot of Respondents' Spaces Satisfaction (As Presented in Table 11)

Table 12 The influence of the IEQ on personal control

Panel A; Estimation results "Personal Control"						
		MS	EGW	MJ	H	SC
Thermal	Coefficient	-0.258	0.239	0.473	-0.097	0.493
	SE	-0.063	-0.125	-0.394	-0.044	-0.279
	t-value	4.095	-1.912	-1.201	2.205	-1.767
	P-value	**0.000**	**0.059645**	**0.233**	**0.030**	**0.081**
Air Quality	Coefficient	0.238	0.197	-0.818	-0.395	0.356
	SE	-0.108	-0.043	-0.474	-0.123	-0.112
	t-value	-2.204	-4.581	1.726	3.211	-3.179
	P-value	**0.031**	**0.000**	**0.088**	**0.002**	**0.002**
Acoustic	Coefficient	0.109	0.018	1.428	-0.248	0.54
	SE	-0.036	-0.009	-1.019	-0.265	-0.283
	t-value	-3.028	-2.000	-1.401	0.936	-1.908
	P-value	**0.003**	**0.049**	**0.165**	**0.352**	**0.060**
Lighting	Coefficient	0.394	0.229	0.467	-0.189	0.174
	SE	-0.103	-0.112	-0.398	-0.042	-0.027
	t-value	-3.825	-2.045	-1.173	4.500	-6.444
	P-value	**0.000**	**0.044**	**0.244**	**0.000**	**0.000**
Layout	Coefficient	0.621	0.453	-0.457	0.373	0.065
	SE	-0.379	-0.129	-0.167	-0.248	-0.002
	t-value	-1.639	-3.512	2.737	-1.504	-32.500
	P-value	**0.105**	**0.001**	**0.008**	**0.137**	**0.000**
Panel B, Goodness of fit						
R-Square		0.325	0.445	0.529	0.475	0.682
F-test		4.867	2.243	1.124	1.678	3.852
DW		1.614	1.961	2.061	1.734	1.778
*, **, *** indicate that F-test is significant at 1%, 5%, and 10% respectively.						
SE: refer to Standard Error which is in parentheses						

Table 13 The influence of IEQ on responsiveness

Panel A; Estimation results "Personal Control"

		MS	EGW	MJ	H	SC
Thermal	Coefficient	-0.258	0.239	0.473	-0.097	0.493
	SE	-0.063	-0.125	-0.394	-0.044	-0.279
	t-value	4.095	-1.912	-1.201	2.205	-1.767
	P-value	**0.000**	**0.059645**	**0.233**	**0.030**	**0.081**
Air Quality	Coefficient	0.238	0.197	-0.818	-0.395	0.356
	SE	-0.108	-0.043	-0.474	-0.123	-0.112
	t-value	-2.204	-4.581	1.726	3.211	-3.179
	P-value	**0.031**	**0.000**	**0.088**	**0.002**	**0.002**
Acoustic	Coefficient	0.109	0.018	1.428	-0.248	0.54
	SE	-0.036	-0.009	-1.019	-0.265	-0.283
	t-value	-3.028	-2.000	-1.401	0.936	-1.908
	P-value	**0.003**	**0.049**	**0.165**	**0.352**	**0.060**
Lighting	Coefficient	0.394	0.229	0.467	-0.189	0.174
	SE	-0.103	-0.112	-0.398	-0.042	-0.027
	t-value	-3.825	-2.045	-1.173	4.500	-6.444
	P-value	**0.000**	**0.044**	**0.244**	**0.000**	**0.000**
Layout	Coefficient	0.621	0.453	-0.457	0.373	0.065
	SE	-0.379	-0.129	-0.167	-0.248	-0.002
	t-value	-1.639	-3.512	2.737	-1.504	-32.500
	P-value	**0.105**	**0.001**	**0.008**	**0.137**	**0.000**
Panel B, Goodness of fit						
R-Square		0.325	0.445	0.529	0.475	0.682
F-test		4.867	2.243	1.124	1.678	3.852
DW		1.614	1.961	2.061	1.734	1.778
*, **, *** indicate that F-test is significant at 1%, 5%, and 10% respectively.						
SE: refer to Standard Error which is in parentheses						

Table 14 The influence of IEQ on the Building Depth

Panel A; Estimation results "Responsiveness"						
		MS	EGW	MJ	H	SC
thermal	Coefficient	0.431	0.221	-0.358	-0.848	-0.237
	SE	-0.226	-0.135	-0.207	-0.311	-0.121
	t-value	-1.907	-1.637	1.729	2.727	1.959
	P-value	**0.060**	**0.106**	**0.088**	**0.008**	**0.054**
Air quality	Coefficient	0.358	0.293	-0.134	-0.372	0.362
	SE	-0.181	-0.134	-0.073	-0.227	-0.169
	t-value	-1.978	-2.187	1.836	1.639	-2.142
	P-value	**0.052**	**0.032**	**0.070**	**0.105**	**0.035**
acoustic	Coefficient	0.413	-0.417	-0.615	-0.651	0.289
	SE	-0.209	-0.155	-0.286	-0.338	-0.153
	t-value	-1.976	2.690	2.150	1.926	-1.889
	P-value	**0.052**	**0.009**	**0.035**	**0.058**	**0.063**
lighting	Coefficient	0.265	0.373	-0.224	-0.165	0.672
	SE	-0.084	-0.181	-0.105	-0.068	-0.123
	t-value	-3.155	-2.061	2.133	2.426	-5.463
	P-value	**0.002**	**0.043**	**0.036**	**0.018**	**0.000**
Layout	Coefficient	0.842	0.431	-0.171	-0.096	0.474
	SE	-0.325	-0.137	-0.046	-0.016	-0.121
	t-value	-2.591	-3.146	3.717	6.000	-3.917
	P-value	**0.011**	**0.002**	**0.000**	**0.000**	**0.000**
Panel B, Goodness of fit						
R-Square		0.638	0.807	0.565	0.405	0.896
F-test		3.173	11.714	2.301	1.905	15.447
DW		2.185	2.447	1.485	1.511	2.267
*, **, *** indicate that the test is significant at 1%, 5%, and 10% respectively.						

Table 15 The influence of IEQ on the Workgroups

Panel A; Estimation results "Building Depth"						
		MS	EGW	MJ	H	SC
thermal	Coefficient	0.278	0.405	-0.294	-0.142	-0.304
	SE	0.271	0.317	0.345	0.023	0.143
	t-value	1.026	1.278	-0.852	-6.174	-2.126
	P-value	0.308	0.205	0.397	0.000	0.037
Air quality	Coefficient	0.592	0.171	-0.494	-0.361	-0.273
	SE	0.237	0.089	0.215	0.179	0.129
	t-value	2.498	1.921	-2.298	-2.017	-2.116
	P-value	0.015	0.058	0.024	0.047	0.038
acoustic	Coefficient	-0.418	-0.007	0.734	0.054	0.303
	SE	0.372	0.221	0.892	0.319	0.298
	t-value	-1.124	-0.032	0.823	0.169	1.017
	P-value	0.265	0.975	0.413	0.866	0.312
lighting	Coefficient	-0.846	0.119	0.516	0.153	0.193
	SE	0.641	0.057	0.411	0.205	0.239
	t-value	-1.320	2.088	1.255	0.746	0.808
	P-value	0.191	0.040	0.213	0.458	0.422
Layout	Coefficient	0.463	0.246	-0.673	0.356	0.214
	SE	0.390	0.195	0.632	0.297	0.236
	t-value	1.187	1.262	-1.065	1.199	0.907
	P-value	0.239	0.211	0.290	0.234	0.367
Panel B, Goodness of fit						
R-Square		0.581	0.617	0.519	0.319	0.42
F-test		2.532	4.502	1.079	1.311	1.302
DW		1.913	2.376	1.358	1.429	1.576
*, **, *** indicate that F-test is significant at 1%, 5%, and 10% respectively.						

Table 16 Correlations Analysis

	Michael Sterling	Eastern Gateway	Marie Jahoda	Howell Building	Stem Centre
Thermal Comfort	0.225*	-0.260	0.244	-0.185	0.431*
Indoor Air Quality	-0.038	0.523	0.352**	0.602*	-0.384
Acoustic Environment	0.101	0.394**	0.172	0.193	0.194
Lighting Environment	0.335	-0.478	0.214*	0.516**	0.577
Layout	0.227	-0.372	0.207*	0.556	0.398
aesthetic	0.213*	0.207*	0.165	0.197	0.189*

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).