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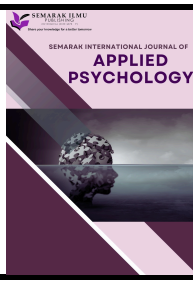

Sustainable Co-Working Spaces in Education Institutions: A Data-Driven Analysis of Attributes Influencing Human Interaction

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ABSTRACT

Co-working spaces have gained significant attention as flexible work environments. However, the specific attributes of sustainable co-working spaces that most influence human interaction, particularly in educational institutions, remain underexplored. There is a lack of such space in education institutions for students' self-studying and self-development outside of formal learning hours. This study focuses on respondents within educational institutions, addressing a significant research gap in sustainable co-working space design for these settings. It aims to identify and evaluate the impact of sustainable co-working space attributes on human interaction. An online survey was developed on Google Forms and distributed via social media platforms, resulting in 65 responses from persons from various levels of education institutions. Using survey data collected from participants, the perceived impact of various attributes – ranging from functional attributes to sustainable attributes – was analysed. A combination of descriptive statistics, ANOVA tests, and post-hoc analyses were conducted to examine significant differences in the perceived impacts of these attributes. Results reveal that core attributes like internet access and open layouts significantly enhance human interactions, while sustainability-focused attributes like green furniture and energy-efficient designs exhibit lower perceived impact. The findings were translated into a prototype sustainable co-working space for a future validation study. These findings underscore the importance of prioritising attributes that foster communication and collaboration in sustainable co-working space design for educational institutions. The study provides actionable recommendations for creating user-centric, sustainable co-working spaces that optimise human interaction.

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1. Introduction

Co-working spaces have emerged as a transformative concept in workplace design, offering flexible, shared environments that foster collaboration, innovation, and community building. Originally developed for entrepreneurs and freelancers, co-working spaces have now expanded to various sectors [1]. Sustainable design, another critical trend in architecture and space planning, has further influenced the development of sustainable buildings, communities, and cities, where the inclusion of social dimensions plays a crucial role [2]. However, the interplay between sustainable attributes and their impact on human interactions within co-working spaces in educational institutions remain inadequately explored. Interactions outside of formal learning hours are important not only among students, but also between students and teachers or lecturers. Student development during informal learning hours play as big a role as during formal learning hours, as seen in the educational institution accreditation rules provided by the Malaysian Qualifications Agency (MQA), which highlights the proportions of Student Learning Time (SLT), covering both formal and informal learning hours.

Humans use many social cues to interact with each other, such as using facial and body movement as well as visual and vocal signals [3]. Human interaction is a fundamental component of co-working spaces, facilitating knowledge exchange, teamwork, and a sense of belonging [4, 5]. In the context of education, human interaction is important for the ideal development of students; it also enhances adult learning [6]. Other research has also found that group interactions in education institutions have a big impact towards attaining knowledge [7]. Overall, interactions in education institutions are concerned with many things, including students' background, professional communities, personal communities, and knowledge and skills [8].

As sustainability becomes a global priority, the integration of sustainable design elements into co-working spaces introduces both opportunities and challenges. Despite growing interest in sustainable design, little is known about how such attributes influence social dynamics, particularly in the context of educational institutions. Using survey data and statistical analysis, this study answers a few research questions – RQ1: 'What are the most important attributes in a sustainable co-working space according to respondents from education institutions?', RQ2: 'What are the attributes that foster or hinder human interactions in a sustainable co-working space in an education institution?', and RQ3: 'How far do the perceived impact of each attribute differ from one another?'. The research questions are formulated based on the following hypotheses:

RQ1
- H0 – All attributes have similar importance in a sustainable co-working space
- H1 – Some attributes are considered more important than others

RQ2
- H0 – All attributes promote human interaction
- H1 – Some attributes have a higher impact than others towards human interaction

RQ3
- H0 – All attributes have an equal impact towards human interaction
- H1 – Attributes have significant differences in impact from one another

The findings provide evidence-based recommendations for designing sustainable, socially conducive co-working spaces in educational settings. This study contributes to both theoretical knowledge and practical applications in the fields of sustainable design and educational space planning.

While previous research has extensively studied the effects of co-working spaces on entrepreneurship and professional collaboration, their role in fostering human interaction within educational institutions – where students and faculty increasingly rely on collaboration for learning

and research – remains an under-researched area [9]. While co-working spaces typically offer similar features, there has been a lack of research highlighting sustainable features in a co-working space. In fact, a quick search on Google Scholar using the terms "sustainable co-working space" revealed that out of 37 papers found on Google Scholar, only one paper specifically defines a sustainable co-working space, namely 'What is a Sustainable Coworking Space?' [10]. Even so, their definition of a sustainable co-working space describes the *sustainable activities* in the co-working space, rather than the *physical attributes* of the co-working space. Thus, this paper does not contradict that paper, rather, this paper aims to enhance their definition through an additional lens, i.e. the perspectives of potential users regarding the physical attributes of sustainable co-working spaces in educational institutions. These critical research gaps – the lack of research on sustainable co-working space attributes and the lack of research on the impact of co-working spaces in educational institutions – underscores the need for a focused investigation into how sustainable co-working space attributes impact human interaction in these unique environments.

2. Methodology

This study employed a quantitative approach to investigate the impact of sustainable co-working space attributes on human interaction from the perspectives of respondents in educational institutions. The research targeted students, staff, and visitors of educational institutions. Data were collected through a comprehensive survey designed and distributed via Google Forms, ensuring accessibility and ease of distribution.

2.1 Survey Instrument

The survey consisted of eight compulsory sections and two optional sections, designed to cover a broad range of data on sustainable co-working spaces, as seen in Table 1. However, this paper only focuses on analyzing data from the first three sections.

Table 1
Survey sections

Section	Category	Notes
A: Demography	Compulsory	Discussed in this study
B: Attributes of a sustainable co-working space	Compulsory	Discussed in this study
C: Impact of a sustainable co-working space	Compulsory	Discussed in this study
D: Interactions in existing shared spaces	Compulsory	Discussed in this study
E: Other impacts in existing shared spaces	Compulsory	
F: Other impacts in existing shared spaces	Compulsory	
E: Wellbeing in educational institutions	Compulsory	
H: Example of a sustainable co-working space	Compulsory	
Participation certificate	Optional	
Additional questions	Optional	

Section A collected information on respondents' gender, age, occupation, and personality type. Section B asked respondents to rank the importance of 13 attributes in a sustainable co-working space from most important to least important. Section C asked respondents to rate the perceived impact of each attribute on human interaction, using a scale ranging from 'Very Positive' to 'Very Negative', including a 'Not Applicable' option. Section D asked respondents about their experience in existing shared spaces in educational institutions, and included an open-ended question which asked for suggestions to improve the existing spaces.

The survey was pre-tested to ensure clarity and reliability before full deployment.

2.2 Data Collection

The sampling method used was convenience sampling [11], where the survey was distributed from August to November 2024 through social media channels such as Facebook, LinkedIn, and WhatsApp. To ensure a comprehensive range of viewpoints were captured, the survey included respondents from a variety of educational institutions and levels. This strategy facilitated the collection of data from a diverse population within educational contexts.

2.3 Respondents

The final dataset comprised 65 responses from students, educators, and visitors from various educational levels, including secondary and tertiary institutions. This diverse respondent pool provided insights into how sustainable co-working space attributes influence human interaction among respondents from educational settings. This approach aligns with best practices in survey research, where the inclusion of a diverse range of respondents allow for different perspectives and experiences to be captured [12].

2.4 Data Analysis

The survey data was downloaded as an .xlsx file and analyzed using Python on Google Colab. Python is a coding platform that is used for data analysis and data visualization in many areas such as computational physics [13] and scientific computing [14]. The codes used on Python for this research are shown in Table 2. The analysis focused on the three selected sections of the survey. Descriptive statistics were used to summarize the frequency of responses and calculated the mean and standard deviation of rankings and impact levels. Ranking analysis was used to calculate how often each sustainable attribute was ranked as most important or least important to identify key attributes influencing human interaction. Analysis of Variance (ANOVA) testing was conducted to assess statistically significant differences in the perceived impact of different attributes. 95% confidence intervals were provided to indicate the precision of the estimates. ANOVA testing is commonly used in studies [15, 16] where one or more variables are categorical; in this case, the attributes measured were categorical, and hence other methods such as t-test were not used. Next, post-hoc analyses were performed to identify attributes with significant pairwise differences. Post-hoc analyses are mainly used to highlight differences between means and identify which items are different from one other. Post-hoc analysis is used by many researchers for this purpose [17-19]. The more popular type is the Tukey's Honestly Significant Difference (HSD) test, seen in many previous studies [20-22]. Lastly, data visualization developed using Python and Microsoft Excel such as heatmaps and bar charts were used to present the findings. Heatmaps are commonly used to show different values using different depths of colors and are one of the most common visualization tool used to compare numerical values, as seen in recent research papers [23-25].

Table 2
Codes used on Python for data analysis

Code	Purpose
question = 'Occupation' response_counts = data[question].value_counts() table_data = pd.DataFrame({'Response': response_counts.index, 'Count': response_counts.values}) table_data	Count responses and create a table for the question 'Occupation'
rank_counts = data.apply(pd.Series.value_counts)	Count frequency of each rank for every attribute
average_ranks = data.mean() average_ranks = average_ranks.sort_values()	Calculate average rank for each attribute and sort attributes by average rank
import seaborn as sns plt.figure(figsize=(10, 8)) sns.heatmap(rank_counts, annot=True, cmap='YlGnBu', fmt='.0f') plt.title('Frequency of Ranks for Each Attribute') plt.xlabel('Attributes') plt.ylabel('Ranks') plt.show()	Create a heatmap of rank distribution
average_scores = data_numeric.iloc[:, 1:].mean(axis=1) sorted_data = data_numeric.sort_values('Average Score', ascending=False)	Calculate average impact score for each attribute and sort the data (descending)
import scipy.stats as stats anova_results = stats.f_oneway(*[data[data['Sustainable Feature'] == feature]['Impact Level'].dropna() for feature in data['Sustainable Feature'].unique()])	Perform ANOVA on the impact level
from statsmodels.stats.multicomp import pairwise_tukeyhsd tukey = pairwise_tukeyhsd(endog=data['Impact Level'], groups=data['Sustainable Feature'], alpha=0.05)	Perform Tukey HSD post-hoc test

2.5 Ethical Considerations

Participation in the survey was voluntary, and informed consent was obtained at the beginning of the survey, as seen in Figure 1. If respondents chose to not give consent, they were asked to close the survey window. The survey ensured anonymity to maintain confidentiality and protect respondents' privacy.

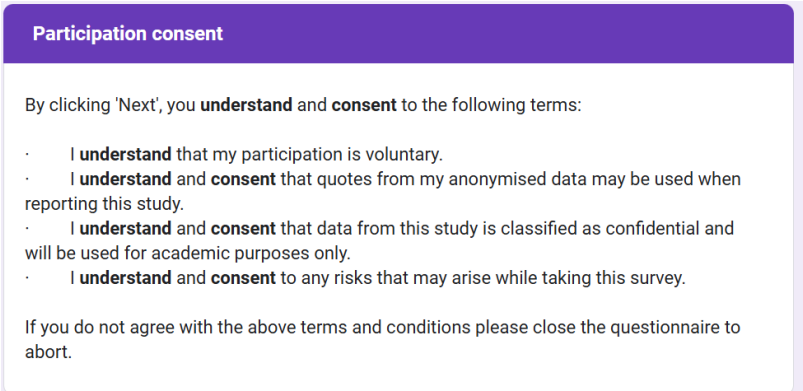

Fig. 1. Informed consent

2.6 Development of Prototype

Based on the results of this study, a prototype sustainable co-working space was developed by incorporating the attributes included in the survey. The prototype will be used for a future validation study to measure the actual impact of the attributes towards human interactions.

3. Results

3.1 Descriptive Statistics

The survey collected responses from a total of 65 individuals from various educational institutions, including students, lecturers, and visitors. Figure 2 summarizes the demographic breakdown of respondents. From Figure 2, it can be seen that the largest group of respondents comprised Universiti Teknikal Malaysia Melaka (UTeM) undergraduate students (39%), followed by UTeM postgraduate students (20%). Respondents from other institutions included students (12%) and teachers (12%). Academic staff at UTeM accounted for another 12%, with lecturers from other institutions making up 3%. The smallest group of respondents (2%) was UTeM visitors. Surveys are designed to collect data from a subset of a population [26]; therefore, the diverse demographic composition ensured that a broad range of perspectives are captured.

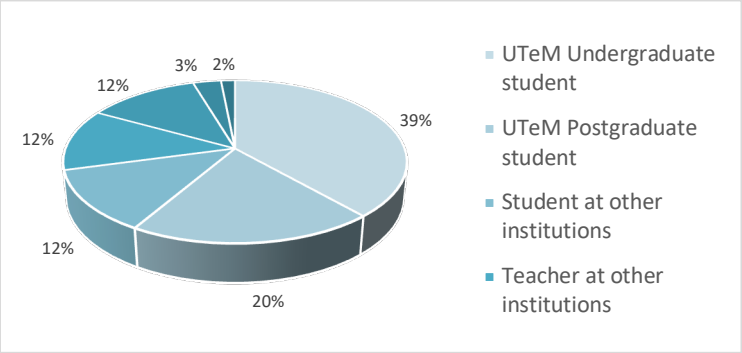

Fig. 2. Demographic breakdown of survey respondents

3.2 Ranking Analysis of Sustainable Attributes

Respondents were tasked with ranking sustainable attributes of co-working space on a scale of 1 to 5, with 1 representing the most important and 5 the least important. The frequency of each ranking is reflected as a heatmap in Figure 3, where darker colors reflect higher values while lighter colors reflect lower values.

Figure 3 shows that open layout (n =37) and access to internet (n = 36) had the highest frequency of being ranked as the most important attributes. The positive impact of an open layout towards human interaction seems self-explanatory, given that it is much easier to interact with each other when there are no physical barriers. Additionally, in this day and age, access to internet is a necessity for every person – one might suggest that it can be considered one of the basic needs in Maslow's hierarchy of needs. Given that a co-working space also acts as a discussion space, the current education landscape requires internet connection in order for students and educators to access online materials to deepen their knowledge and understanding for such discussions. This aligns with many high-impact research that highlights the importance of internet connection in discussions and learning sessions [27-29].

On the other hand, discussion area and convenient location had the highest frequencies of being ranked as second-most important attributes. While these values take up a high percentage, a more appropriate measure would be to look at the averages of all rankings, which will be discussed next.

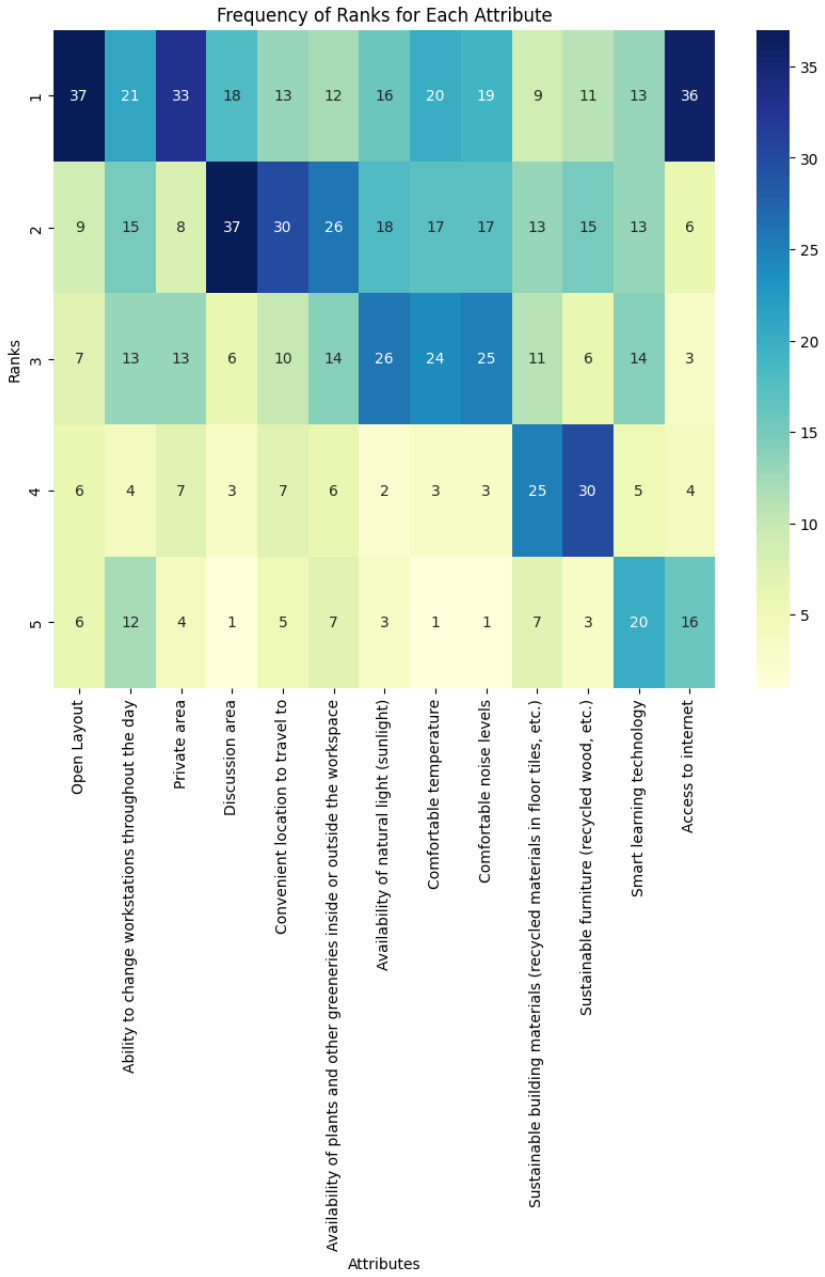

Fig. 3. Frequency of rankings of sustainable attributes

The analysis of average rankings reveals significant insights into the preference of these attributes. The average rankings for each attribute are summarized in Table 3. From Table 3, it can be seen that discussion areas (average rank = 1.95) and open layouts (average rank = 2.00) were ranked as the most important attributes, indicating their critical role in facilitating collaborative and interactive spaces within educational institutions. This aligns with previous research which highlights the preference of such areas in workspaces [4]. Workspaces with open layouts provide users with a space to take breaks, space(s) for collaboration, and allow them to interact with others [30]. Private areas also ranked highly (average rank = 2.09), suggesting the need for balance between collaborative

and quiet spaces. Meanwhile, functional comfort attributes such as comfortable temperature (average rank = 2.20) and comfortable noise levels (average rank = 2.23) were preferred moderately by respondents, emphasizing the importance of ergonomic factors. In fact, past research has highlighted the supporting role of ergonomics in corporate interactions [31]. Attributes related to aesthetics and connectivity, such as natural light (average tank = 2.35) and internet access (average rank = 2.35), were similarly moderately valued. Attributes primarily associated with environmental sustainability, such as sustainable furniture (average rank = 2.98) and sustainable building materials (average rank = 3.12), were considered less critical by respondents. Smart learning technology also ranked lower (average rank = 3.09), reflecting a focus on fundamental needs over advanced technological attributes.

Table 3
Average rankings of sustainable attributes

Attribute	Average Rank
Discussion area	1.95
Open Layout	2.00
Private area	2.09
Comfortable temperature	2.20
Comfortable noise levels	2.23
Availability of natural light (sunlight)	2.35
Access to internet	2.35
Convenient location to travel to	2.40
Availability of plants and other greeneries inside or outside the workspace	2.54
Ability to change workstations throughout the day	2.55
Sustainable furniture (recycled wood, etc.)	2.98
Smart learning technology	3.09
Sustainable building materials (recycled materials in floor tiles, etc.)	3.12

3.3 Perceived Impact of Sustainable Attributes on Human Interaction

Respondents were asked to evaluate how various sustainable co-working space attributes impacted their human interactions using a Likert scale ranging from “Very negatively impacts my human interactions” (1) to “Very positively impacts my human interactions” (5), with “Not applicable” assigned a score of 0. The average impact scores for each attribute are presented in Figure 4.

From Figure 4, access to internet had the highest average score (4.40), indicating it is perceived as the most impactful attribute in fostering human interaction. This underscores the importance of connectivity in educational co-working environments where collaboration and communication often depend on internet access. Open layout (4.18) and smart learning technology (3.97) followed, emphasizing the role of physical design and technological tools in creating spaces conducive to human interaction. Discussion areas (3.95) also ranked highly, aligning with the need for spaces designed for active communication and network. Meanwhile, functional aspects such as noise level in the workspace (3.80), amenities and facilities (3.77), and ergonomic attributes (3.65) were rated moderately, signifying their secondary but still meaningful role in fostering interaction. Attributes like temperature (3.62) and private areas (3.62) were similarly rated, highlighting the importance of balancing comfort and collaboration in co-working spaces. Lastly, sustainability-focused attributes, such as sustainable furniture (3.22) and sustainable building materials (3.09) were rated lower in terms of their impact on human interaction. This finding suggests that while these attributes may

align with broader environmental goals, they are perceived as having less direct influence on human interaction. Availability of plants and greeneries received the lowest score (2.97), indicating that aesthetic or biophilic elements may play a more supportive rather than primary role in fostering interaction.

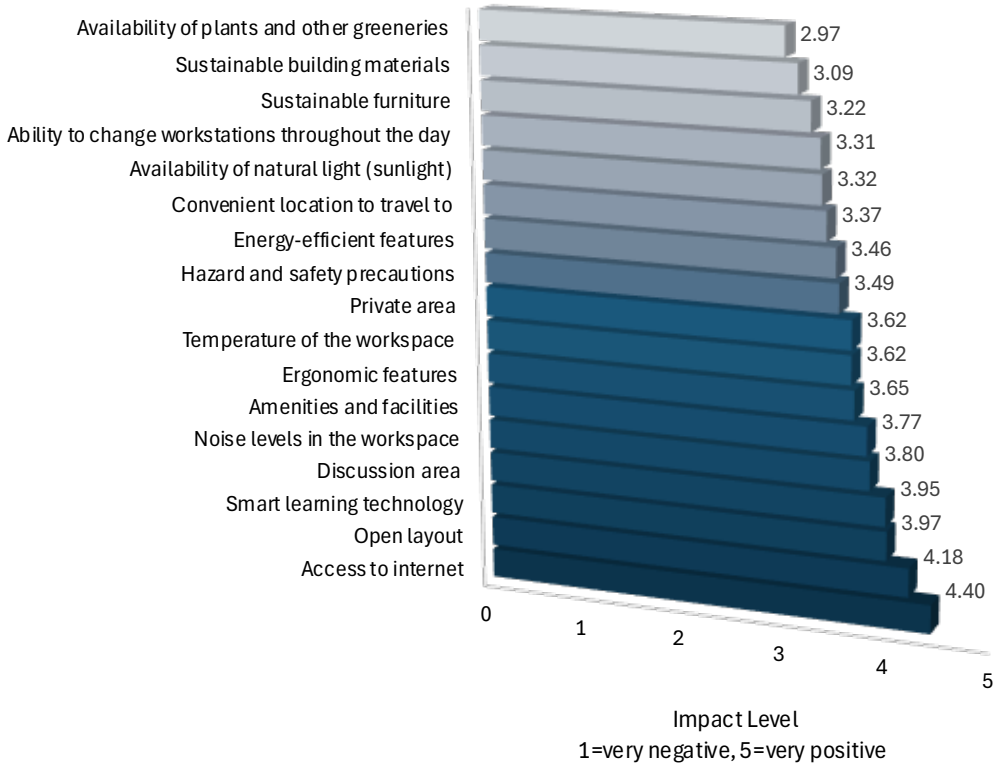

Fig. 4. Average impact level of sustainable attributes towards human interactions

The results demonstrate a clear preference of practical and interactive attributes over sustainability-focused attributes. The high ratings for attributes like internet access, open layouts, and discussion areas highlight the essential role of collaborative and technologically equipped spaces in fostering human interaction within educational institutions. In contrast, sustainability-focused attributes, while valued, were perceived as secondary in their contribution to social dynamics. This suggests that while integrating sustainable elements remains important, they should complement, rather than compete with, the primary functional and interactive aspects of co-working spaces.

These findings align with the responses from Section D of the survey, where respondents were asked about existing shared spaces that they have experienced in educational institutions and provide suggestions to improve those existing spaces to facilitate human interaction. For example, one respondent answered, “Postgraduate lounge – the layout could be rearranged to facilitate better social interaction.” Other answers include “Library – create designated collaboration zones, interactive tools, and comfortable seating”, “Student center – design collaborative spaces and offer virtual collaboration tools” and “Cafeteria – offer mixed seating styles”.

The findings highlight the need for educational institutions to design co-working spaces that facilitate human interaction by focusing on functionality and connectivity. Integrating sustainability should align with these goals to ensure holistic space design that supports both human and environmental needs.

3.4 ANOVA Testing

The results of the ANOVA test, shown in Table 4, revealed statistically significant differences in the perceived impact of sustainable co-working space attributes on human interaction. The F-statistic of 4.93 and the corresponding p-value ($p < 0.001$) strongly suggest that not all sustainable attributes have the same impact on human interactions, and at least some of the sustainable attributes have significantly different impacts on human interaction.

Table 4
ANOVA test result

F-statistic	4.781012444394393
p-value	1.67200253261759e-09

The low p-value indicates strong evidence against the null hypothesis, which assumes that all sustainable attributes have an equal effect on human interaction. This finding highlights the need to identify which specific attributes contribute most significantly to human interaction, providing guidance for choosing design elements in educational co-working spaces.

3.5 Post-hoc Analysis

Since the ANOVA result indicates significant differences, the post-hoc Tukey Honestly Significant Difference (HSD) test was performed to identify which specific sustainable attribute differs from one another in terms of their impact on human interaction. The Tukey HSD test was set to do a pairwise comparison of the means of the dependent variable (impact levels) of the independent variable (sustainable attributes) at the default significance level of 0.05. Given the extensive length of the results, only the reject=TRUE results are shown in Table 5, indicating the specific attributes that reject the null hypothesis which assumes that all sustainable attributes have an equal effect on human interaction. From Table 5, it can be seen that ‘Access to internet’ has the most prominent difference from other sustainable attributes. For example, ‘Ability to change workstations throughout the day’ and ‘Access to internet’ had a mean difference 1.0923 with a 95% confidence interval ranging from 0.2304 to 1.9542. This suggests that access to internet has a more significant impact towards human interaction compared to the ability to change workstations throughout the day. Meanwhile, ‘Access to internet’ and ‘Availability of plants and other greeneries inside or outside the workspace’, had a mean difference of -1.4308 and a p-adj of 0, with a 95% confidence interval ranging from -2.2927 to -0.5689, which indicates that ‘Access to internet’ has a significantly higher impact towards human interaction compared to the availability of plants and greenery. ‘Ability to change workstations throughout the day’ shows a significant difference with ‘Open layout’ with a mean difference of 0.8769 and a confidence interval ranging from 0.015 and 1.7388, indicating that an open layout has a more significant impact towards human interaction compared to the ability to change workstations throughout the day. ‘Availability of plants and other greeneries inside or outside the workspace’ shows significant positive differences with attributes such as ‘Discussion area’ and ‘Open layout’, indicating that the latter significantly impacts human interaction positively compared to the former.

Table 5
Result of Tukey HSD test (pairwise comparison of means)

group1	group2	meandiff	p-adj	lower	upper	reject
Ability to change workstations throughout the day	Access to internet	1.0923	0.0015	0.2304	1.9542	TRUE
Ability to change workstations throughout the day	Open layout	0.8769	0.0412	0.015	1.7388	TRUE
Access to internet	Availability of natural light (sunlight)	-1.0769	0.0019	-1.9388	-0.215	TRUE
Access to internet	Availability of plants and other greeneries inside or outside the workspace	-1.4308	0	-2.2927	-0.5689	TRUE
Access to internet	Convenient location to travel to	-1.0308	0.0042	-1.8927	-0.1689	TRUE
Access to internet	Energy-efficient features (low energy consumption)	-0.9385	0.0176	-1.8004	-0.0765	TRUE
Access to internet	Hazard and safety precautions	-0.9077	0.0272	-1.7696	-0.0458	TRUE
Access to internet	Sustainable building materials (recycled materials in floor tiles, etc.)	-1.3077	0	-2.1696	-0.4458	TRUE
Access to internet	Sustainable furniture (sustainable design, green materials, less production cost, etc.))	-1.1846	0.0003	-2.0465	-0.3227	TRUE
Availability of plants and other greeneries inside or outside the workspace	Discussion area	0.9846	0.0088	0.1227	1.8465	TRUE
Availability of plants and other greeneries inside or outside the workspace	Open layout	1.2154	0.0002	0.3535	2.0773	TRUE
Availability of plants and other	Smart learning technology	1	0.0069	0.1381	1.8619	TRUE

greeneries inside or outside the workspace						
Open layout	Sustainable building materials (recycled materials in floor tiles, etc.)	-1.0923	0.0015	-1.9542	-0.2304	TRUE
Open layout	Sustainable furniture (sustainable design, green materials, less production cost, etc.))	-0.9692	0.0111	-1.8311	-0.1073	TRUE
Smart learning technology	Sustainable building materials (recycled materials in floor tiles, etc.)	-0.8769	0.0412	-1.7388	-0.015	TRUE

The Tukey HSD test identified significant differences in how various sustainable attributes impact human interaction. These results prove that people perceive these attributes differently in terms of their impact on human interaction. Attributes such as 'Access to internet' and 'Availability of plants and greeneries' have significantly different impacts, which could guide the design and implementation of sustainable co-working spaces to improve human interaction.

3.6 Development of a Prototype Sustainable Co-Working Space

The findings from the survey were translated into a prototype sustainable co-working space at the Faculty of Industrial & Manufacturing Technology & Engineering (FTKIP) in UTeM, incorporating the attributes of open space, natural lighting, dynamic seating, ergonomic and sustainable furniture, discussion area, smart learning technology, indoor greenery, and sustainable building materials, as seen in Figure 5. This space serves as a model for a future study that will validate the survey results by assessing the actual impact of these attributes towards human interaction within the co-working space.

Fig. 5. Prototype sustainable co-working space at FTKIP in UTeM

4. Conclusions

This study investigated the relationship between sustainable co-working space attributes and their impact on human interaction among respondents in education institutions. Through a comprehensive survey, key sustainable attributes impacting human interactions were identified, offering insights into how such attributes can be integrated into workspace design to promote a more interactive and collaborative environment.

The ranking analysis of sustainable attributes reflects a clear preference of attributes in sustainable co-working spaces, such as discussion areas and open layouts, over attributes primarily related to environmental sustainability, such as sustainable materials. This suggests that respondents perceive co-working spaces in educational institutions as primarily social and interactive environments, where functionality and comfort are paramount. Additionally, while sustainability-focused attributes were ranked lower, their moderate scores indicate that they are not entirely overlooked. This highlights the importance of integrating sustainability in ways that do not compromise usability of functionality.

The analysis on the perceived impact of sustainable attributes highlighted that attributes such as access to internet, open layout, and discussion area were among the most important attributes in terms of their perceived impact on human interaction. These attributes consistently ranked higher in their influence on human interaction, reflecting their role in promoting communication, collaboration, and engagement within educational co-working spaces. Ergonomic furniture was also identified as a supporting element that enhances comfort, physical well-being, and productivity. By incorporating features such as adjustable seating, proper back support, and dynamic furniture layouts, ergonomic designs help reduce physical strain and accommodate diverse user needs, ensuring prolonged comfort and enabling users to fully engage in social and collaborative activities.

The ANOVA results indicated that there were statistically significant differences in the perceived impact of these attributes, with some attributes demonstrating strong impacts than others. Further post-hoc analysis using Tukey HSD test showed detailed pairwise comparisons of the impact of sustainable attributes, revealing significant differences among various pairs. The results highlighted that attributes like ‘Access to internet’ and ‘Open layout’ had a significantly higher impact on human interaction compared to attributes such as ‘Sustainable building materials’ and ‘Sustainable furniture’. This underscores the importance of internet access and openness in workspace design for encouraging human interaction.

The findings of this study contribute valuable insights into the design and management of sustainable co-working spaces, particularly within educational institutions where the integration of such attributes can promote student and staff engagement. These results suggest that educational institutions should put importance on attributes that promote communication and interaction, such as open layouts, access to internet, and natural elements to create conducive environments for collaboration and social wellbeing.

In conclusion, this study provides empirical evidence on the impact of sustainable co-working space attributes on human interaction. These findings are important for stakeholders in educational institutions when designing spaces that not only promote sustainability but also promote human interactions, thus supporting academic collaboration and promoting a sense of community. The inclusion of ergonomic furniture ensures that comfort and usability remain at the forefront of workspace design, aligning with broader goals of user well-being and productivity. Hopefully, the findings of this study accelerates the achievement of Sustainable Development Goals, i.e. SDG 3 (Good Health and Well-being) to "ensure healthy lives and promote well-being for all at all ages", SDG 4 (Quality Education) to "ensure inclusive and equitable quality education and promote lifelong

learning opportunities for all", SDG 11 (Sustainable Cities and Communities) to “make cities and human settlements inclusive, safe, resilient and sustainable”, and SDG 12 (Responsible consumption and production) to “ensure sustainable consumption and production patterns” [32].

This study primarily focused on students and academic staff from various educational institutions, including UTeM. Future research should include a more diverse demographic range, such as administrative staff, policymakers, and external collaborators, to capture a comprehensive view of the stakeholders involved in educational ecosystems. Expanding the demographic scope would enhance the generalizability and applicability of the findings across different institutional contexts. Additionally, future studies could explore other impacts of the attributes, such as towards productivity and wellbeing of the co-working space users.

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