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Influences of visual preferences expressed by participants on early stage of learning space design: An interactive parametric modelling study[1]

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Abstract

Designing learning spaces in the context of contemporary higher education is increasingly participatory as the users' learning needs and preferences are ever more diverse. This paper presents a study of the influences of visual preferences expressed by participants on early stage of learning space design. The hypothesis is that designers' decision-making in shaping learning spaces may differ if visual preferences expressed by participants are made accessible at early stage of the design process. Employing Web-based 3D parametric modelling, we carried out a participatory experiment involving 186 participants from five countries to interact with a set of visual parameters and alter how the interior of a learning space should look like. Aggregates of the participants' expressions were then made accessible to 18 design practitioners partaking in the second stage of the experiment. 'Positional change' is proposed as a schema to characterise the influences as manifested in the design practitioners' responses. The study shows that the design practitioners generally agreed that the visual preferences expressed by the participants had influences on them. The 3D parametric virtual Environment (p-VE) developed for the study is described in some detail, which can be further extended to facilitate user-designer partnership in co-design of learning spaces.

Keywords: learning space design; visual preference; user participation, interactive parametric modelling; positional change

1. Introduction

Learning spaces as Learning Landscapes has emerged as a new paradigm underpinning the research and development of university campuses, learning resource centres and library

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buildings in the 21st century (Dugdale 2009; Boys 2010, Among various types of learning spaces (e.g., teaching spaces, libraries, personal/communal study rooms, etc.), we consider social learning spaces as the focus of our design study. In higher education institutions, social learning spaces are often used by a large number of users of diverse backgrounds (social, cultural, educational, etc.). The user population inhabiting daily in such learning spaces is typically in the range of several hundred to a thousand or more for medium-large learning resources centres (Lewis 2010, Poole and Wheal, 2011; Peng 2012).

In the present paper, we report on a study of how user-centred design of learning spaces in higher education can be further developed by uncovering a user population's visual preferences at early stage of the design process. The research hypothesis is twofold: (1) that participants can articulate their design preferences if provided with permutations of spatial dimension, pattern, colour and other associated visual attributes of learning spaces; (2) that user expressed visual preferences data collated from a large-scale user participatory campaign can be influential to design practitioners in decision-making. We develop a method and implement an experimental Web-based platform aimed at collating and analysing visual preferences expressed by anyone interested in learning space design anywhere anytime.

In urban and architectural design, most of the existing visual preference survey methods are implemented in physical means/media, constraining time, space and size of user participation. By adopting a digital approach in this study, we develop and evaluate the efficacy of a visual preference survey platform, named as p-VE (parametric Virtual Environment), for initiating large-scale participation in expressing visual preferences of learning spaces to inform early design decision-making. Using p-VE, we carried out a two-stage experiment of visual preference survey in learning space design receiving as many as 186 participants.

2. Visual preference survey and design with users

In the late 1970s, Anton Nelessen developed Visual Preference Survey (VPS) aimed to obtain public feedback on environment quality. Initially developed to assess the urban environment, the VPS method gained popularity and has been applied in other design areas such as product and landscape design. In one of the surveys conducted, Nelessen interacted with the residents of Metuchen (New Jersey, US) and invited them to inspect 320 slides as a ranking exercise. The aim was to elicit what common scenes of the local area that the residents like and dislike (DePalma 1989). Over time, the VPS has become an established method to obtain public responses to visual quality in both research and professional settings, for example, Scott used photographs to investigate the visual factors that influenced people’s preferences in commercial spaces (Scott 1993). Similarly, Stamps used the VPS approach on several occasions to study building façade design (Stamps 1999; Stamps 2004). More recently, Salama and co-workers carried out a visual preference survey as part of a multi-layered methodological approach to uncovering how the physical and spatial attributes of St. Enoch Square are related to the urban life in Glasgow City Centre, Scotland (Salama et. al. 2017).

Im defined visual preference of a place as an individual's or group's like or dislike for the visual appearance of a place; visual preferences can be influenced by a number of physical variables such as texture, colour and shape of space components, also ratios among space dimensions (Im 1984). Scherer later argued that preference as a relatively stable judgement in the sense of liking and disliking a stimulus determined by collative properties, i.e. narrow-wide, short-tall (Scherer 2005). Although Scherer believed preferences bearing little impact on behaviour, Im and Scott insisted that visual preferences could play important roles in designing aesthetically pleasing places that induce positive behaviour (Im 1984; Scott 1993). As more people around the world experiencing formal education from a younger age, participants in higher education are increasingly the experts of their social learning experiences. However, mostly knowing their visual preference, people often struggle to express it (Abercrombie 1991). To bring the expertise out, Sanders and Stappers suggested providing the participants with an appropriate tool such that they become creative individuals (Sanders & Stappers 2012).

Prior to the ubiquity of the Internet, computing technologies have been utilised by some pioneers to facilitate user participation in design to account for personal preferences. Mitsuo Nagamachi developed the Kansei Engineering method to translate human affective words into a product's characteristic (Nagamachi 1995). As an application for interior design, Nagamachi developed the HULIS (Human Living) System that can translate user's affective words into design visualisations. In building design, Richens and Trinders demonstrated one of early uses of 3D simulation for user participation in evaluating design proposals (Richens & Trinders 1999). The 3D simulation was produced using the then popular game engine Quake II to visualise the design of the new Computing Laboratory at the University of Cambridge. As a special high-end computer was required to run the game-engine, the 3D simulation part of the experiment was carried out separately from distributing the building plans and receiving feedback from the participants using e-mail.

3. A large-scale visual preference survey method and system implementation

To acquire a broader basis for investigating learning space design, we consider the need to extend existing visual preference survey (VPS) such that: (1) large-scale participation from anyone interested in expressing visual preferences of learning spaces anytime anywhere can be initiated and sustained over a flexible timeframe; (2) an agile data processing capability can be developed to generate visual analytics of the VPS data collated which could enable participation in learning space design with users.

We initially define a large-scale VPS (L-VPS) method to elicit more involvement from potentially a large number of participants. The method is designed to invite participants to reflect and construct scenes of preferred design solutions based on their personal experiences of inhabiting learning spaces. Instead of asking participants to choose between pre-made images as in conventional VPS, the proposed method expects prospective respondents to actively create their solutions. Therefore, participants with or without expertise in designing learning spaces can become active agents through their direct actions of altering visual factors, composing preferred combinations of visual attributes, and eventually, creating an artefact. Figure 1 summarises the key elements (a-f) of the proposed L-VPS method.

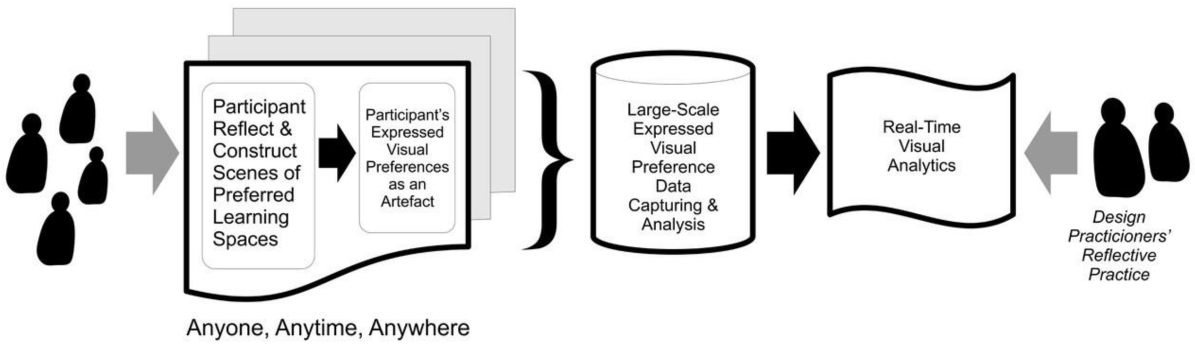


Figure 1. The key elements of a Large-Scale Visual Preference Survey (L-VPS) method for designing learning spaces with participants

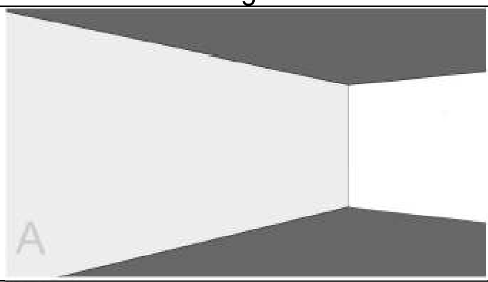
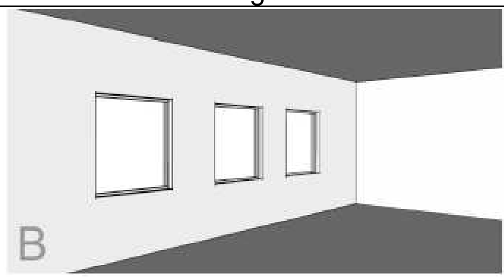
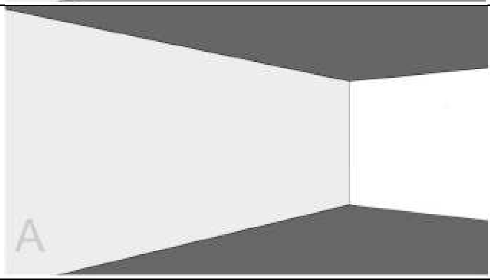
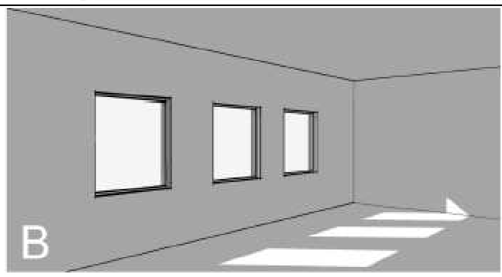
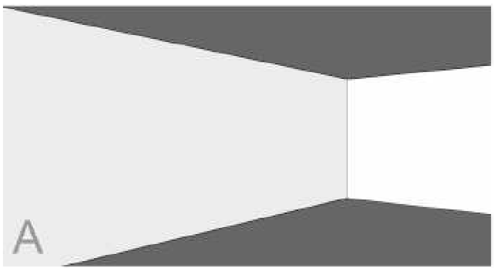
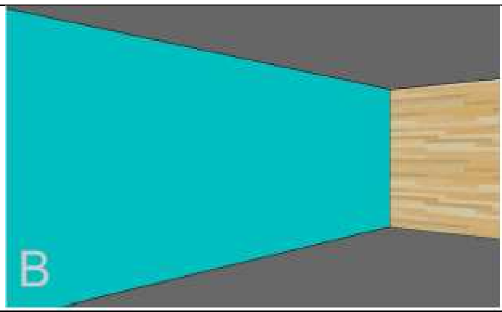
Following the concepts and goals of the L-VPS method as set out above, a preliminary scoping study was carried to inform how the method could be implemented as an interactive visualisation platform, and which visual factors should be included. Below we first present a generic scheme of learning space design to focus on the key visual factors identified in the scoping study. We then describe in some detail our current design and implementation of the experimental Web application p-VE.

3.1. Preliminary scoping study

To determine the scope of visual factors relevant to user preferences of learning spaces, a questionnaire was constructed based on an earlier study by Suzanne C. Scott (Scott 1993) where 11 visual factors that influence preferences of commercial interior environments were identified in the study (Table 1). In our questionnaire design, each of the visual factors is presented as a pair of schematic images comparing two contrasting conditions of a collative visual and spatial property.

Table 1. Ranked visual factors from the preliminary scoping study (All factors received 23 responses, except *Lighting composition* received 17 responses)

	Visual Factors	Unimportant	Less Important	Undecided	Important	Very Important	Mean Rating
1	Presence of Windows	0	0	0	20	70	3.91
2	Natural Light	0	0	0	22.5	65	3.80
3	Surface Colour, Texture & Pattern	0	-5	0	22.5	55	3.15
4	Space Quality: Scale	0	-5	0	30	45	3.04
5	Spatial Organization	0	-7.5	0	22.5	55	3.04
6	Lighting Type i.e. warm/colour	0	-2.5	0	32.5	35	2.83
7	Lighting composition	0	-5	0	17.5	25	2.21
8	Sense of Shape/ Geometric Shape	0	-5	0	22.5	30	2.07
9	Complexity of Visual Elements	0	-12.5	0	25	25	1.63
10	Presence of Plants	-5	-17.5	0	30	10	0.76
11	Presence of Arts: Painting/Sculpture	-10	-15	0	27.5	15	0.76

	Image A	Image B
Presence of Windows		
Natural Light		
Surface Colour, Texture & Pattern		

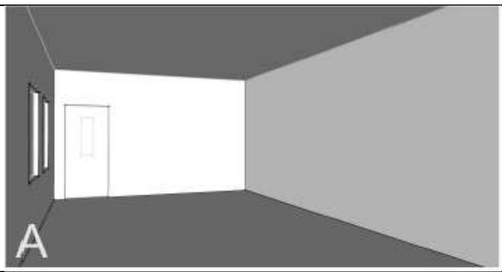
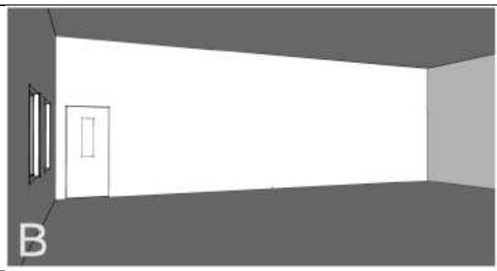
Space Quality: Scale		

Figure 2. The top four collative image sets ranked in the preliminary scoping study

3.2. Simulation of learning space design

Due to time and resources limitations, only the top four visual factors are selected in the current study (Figure 2): Presence of Windows, Natural Light, Surface Colour, Texture & Pattern, and Space Quality (Scale). Since the geometric shape factor is excluded, a simple rectangular box was used to simulate the interior of a learning space in order to focus on the selected four visual factors (Figure 3). A simple city landscape was included for the outside view.

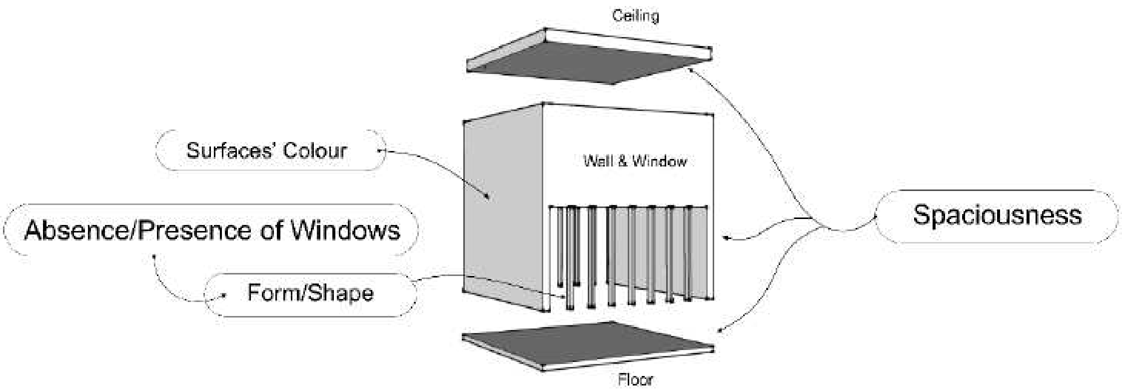


Figure 3. Use of a simple rectangular box for simulation of learning space design focusing on the top four visual factors identified in the preliminary scoping study

3.3. System design and implementation

A set of simple 3D objects were created using SketchUp and then imported into the Unity 3D representing separate components of spatial enclosure of the interior, i.e. the walls, floors, and ceilings. Unity3D (a game engine developed by Unity Technologies) and PlayMaker (a visual scripting environment for Unity3D) were used to compose and add real-time interactivity to the objects. The pilot implementation was packaged into a Web-based 3D parametric virtual environment (p-VE, Figure 4). Parametric modelling was introduced here to provide the interactivity for participants' exploratory behaviour and the permutation of visual stimuli to evoke articulation of visual preferences.

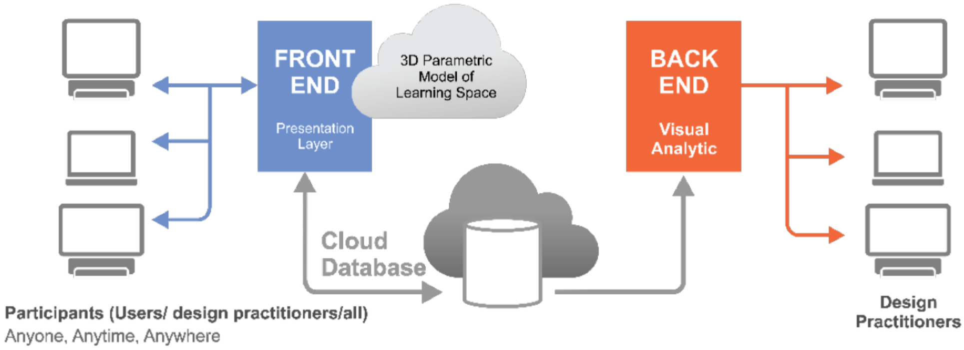


Figure 4. System architecture of a Web-based 3D parametric virtual environment (p-VE)

Our current p-VE prototype implementation provides participating users with the following features:

1. *Introduction*, an introductory pop-up window that explains the purpose of the study, the task participants expected to perform, which is to expect the participants to express his/her visual preferences of a learning space; and the participants' freedom to terminate anytime.
2. *Sign Up/Login*, to set up a user account and login in with a unique User ID.
3. *Demographic*, to provide basic demographic data (such as gender, occupation, and location). Afterwards, the user is introduced to a 3D simulation representing a learning space design. The default space has a generic appearance with no windows to begin with.
4. *Navigation Helper*, a pop-up window to inform users of the various function keys for 3D navigation. Pressing the Navigation keys, users can explore and look around the virtual world. Whenever feeling comfortable with the user interface, users can move to the next section to alter the appearance of the learning space as a single room setting.
5. *Spatial Dimensions*, multiple interactive sliders to change the room's dimensions interactively. Each side of the floor area is expandable from 2m to 16m, while the ceiling height is adjustable from 3m to 7.5m.
6. *Window Patterns*, to choose one of six variant patterns of window opening into the wall surface as shown in Figure 5. The patterns are freely interpretations of 'popular' and 'high' styles as discussed by Stamps with regard to visual preferences of architectural styles (Stamps 1997). The popular styles are the patterns that usually found in magazines, while the High styles has atypical or eccentric features.
7. *Wall Colours*, to change the colour of the wall surface using the Red/Green/Blue sliders. Manipulation of the RGB sliders will generate a synthetic colour on the user's screen. In the piloting stage, only the wall colour can be changed.

8. *Questionnaire*, to make a short assessment of his/her experience with the application using a 5-point Likert-scale on a set of statements prompting several usability issues of p-VE.
9. *Finish*, to send the user data to a cloud-backend database hosted on the Parse service. Each modelling outcome (scene) is considered as a record of visual preference. Visual analytics is then generated from all records collated over a survey period. Figure 6 shows screen captures of the graphical front-end of the p-VE platform.

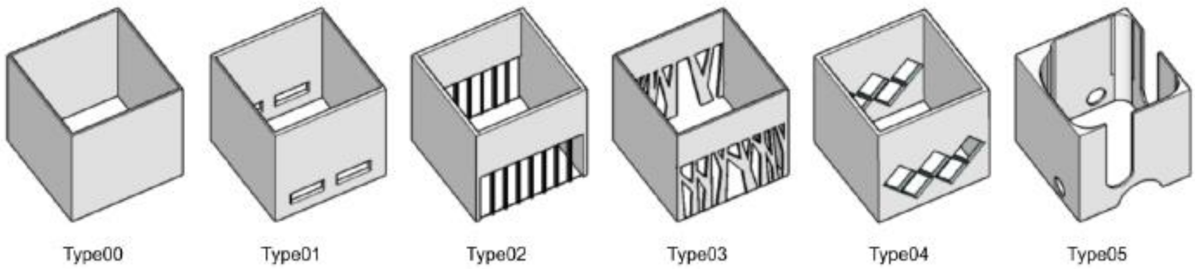
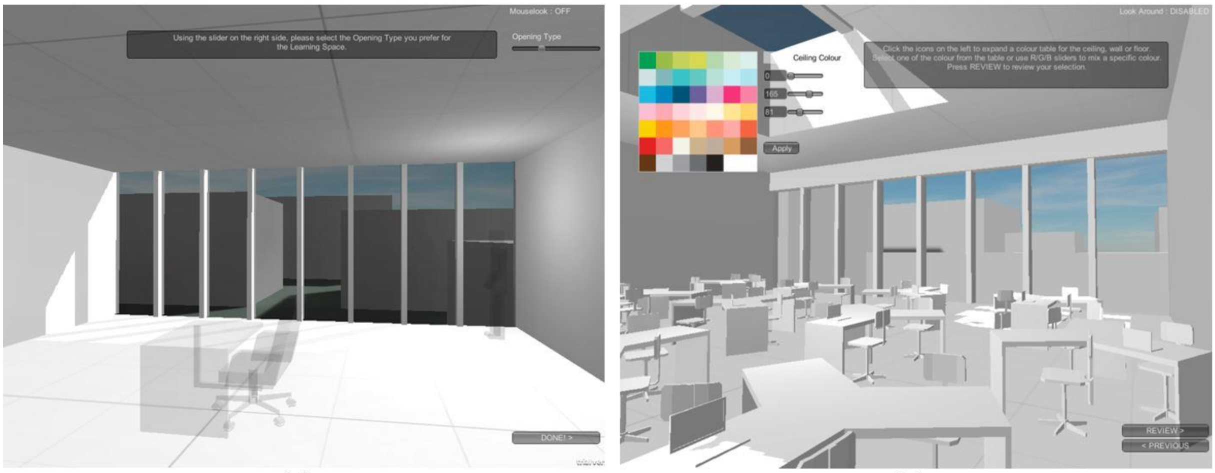


Figure 5. Proposed style variations of Window Patterns in the p-VE implementation



(a) (b)

Figure 6. Screen shots of the front-end of the p-VE platform: (a) An earlier version used piloting test, (b) A later version used in the L-VPS Experiment

A piloting test was conducted with 19 participants, consisting of students in higher education and designers from three countries. A short questionnaire concerning the usability is provided in the end for participants to respond. The first three statements are the principal component of usability test (Lewis 1995) including: (1) overall ease of use, (2) adequacy of the support information provided to complete the tasks, and (3) the length of time it takes to complete the tasks regarding the adequacy of p-VE to express visual preferences. The piloting test confirmed seamless operability of the p-VE platform over the Internet and deposits of artefacts created on the cloud database. Among the feedbacks received, a few participants commented on the difficulty of altering colours using RGB sliders. One participant queried about the ability to change the ceiling's style and lighting type, also a request to include more furniture to give a better 'atmosphere' of the learning space. Based on the comments and feedbacks received from the piloting test, some changes were implemented including:

- The addition of a 48-colour palette for altering surface colours (see Figure 6.b).
- The inclusion of more furniture that covers most of the floor area. The colour of the furniture is set in a neutral white colour and it not yet editable by users (Figure 6.b).
- The addition of Ceiling Style. There are six options to choose from for the ceiling design, perceived as 'popular' and 'high' style (Figure 7).

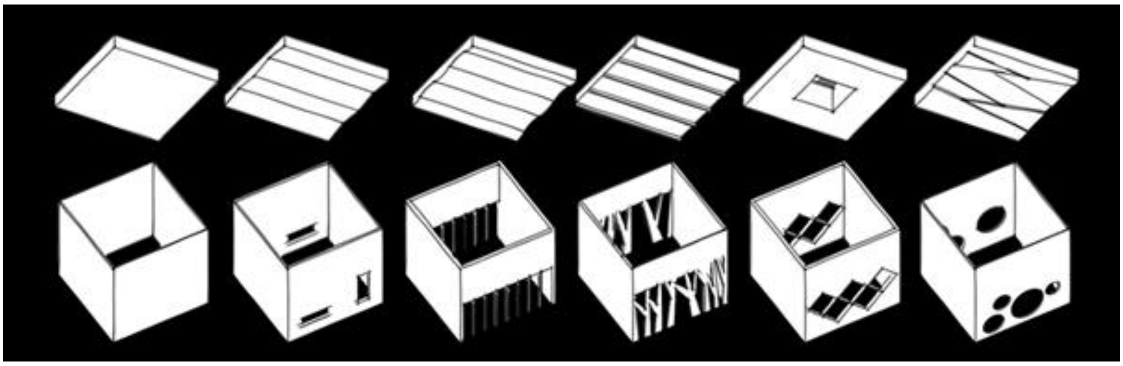


Figure 7. Six window and ceiling styles implemented in the p-VE application

To address the concern here that the participants might need to review and detect unintended random errors during interaction with p-VE, the following changes were implemented:

- The addition of *Review* section, after completing the task the respondents can reflect on their creation and make final decisions before submitting it.
- The addition of *Confidence Rating* feature to allow users to indicate how confident they feel in expressing visual preferences using p-VE. Here it should be noted that it is not gauging merely the confidence of participants' using p-VE to express their preferred design variations but also the extent of correspondence they feel about the graphical virtual environment to their reflections on learning space experiences.

To further improve p-VE's usability, the following changes were implemented in the latest version, which was used in the subsequent experiment.

- Colour changes for all surfaces including Wall, Ceiling, and Floor
- An increased level of brightness in the outdoor environment of the model

- The range of Ceiling height changes to 2–8 m, offering a wider spectrum of height preference
- Swapping the order of Surface Colours with Element Styles such that the order of interaction becomes: Spatial Dimensions → Element Styles → Surface Colours
- The revised sequence of interaction with p-VE is summarised in Figure 8

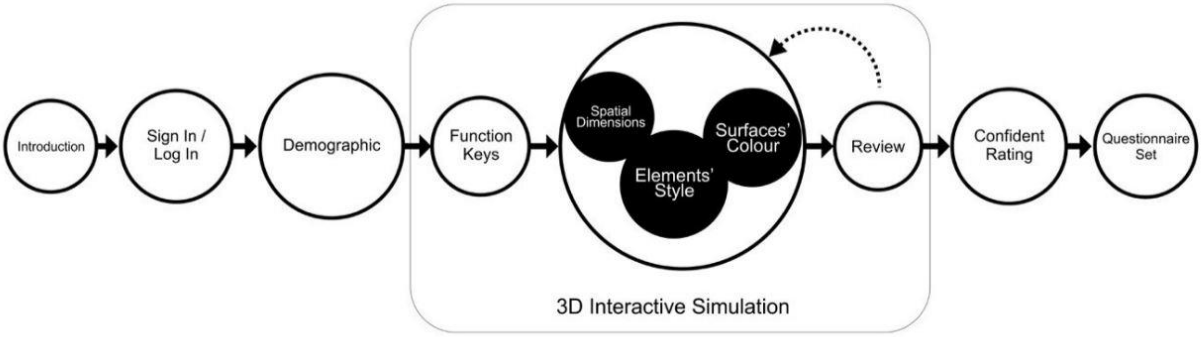


Figure 8. The overall sequence of user interaction with the p-VE application

4. Design of experiments: general participants and design practitioners

Using our latest p-VE application, an experiment of a large-scale visual preference survey in learning space design was carried out in two stages: Experiment 1 with general participants and Experiment 2 with professional design practitioners. The results of the experiment are presented and discussed below.

Experiment 1: general participants

Invitations were circulated through email and social media platforms with links to the p-VE site embedded. A few volunteers were recruited to help eliciting more participants. Although students in higher education were aimed at, the experiment was open to participation from other social groups interested in the use and design of learning spaces. Therefore, in fact any person with Internet access and able to run p-VE can take part in Experiment 1. At the 'Demographic' step (Figure 8), participants were asked to provide some background information such as location, gender and occupation. The anonymised demographic data collected was used in the analysis of the visual preferences collated via p-VE.

Experiment 2: design practitioners

Experiment 2 was designed to aim at participants with a design background. Here the participants were asked to perform the same interaction with p-VE as in Experiment 1 under the circumstance that they were provided with the VPS results from Experiment 1. This is to explore if the participants' choices were affected by their awareness of the VPS results of Experiment 1. Would they produce results different from Experiment 1?

All participants took part in Experiment 2 were required to have used p-VE previously. Prior to the start of Experiment 2, the invited designers were shown an analysis of the Experiment 1 results presented as infographics displaying distributions of the preferences expressed under each visual category (i.e. Preferred Wall colour, etc.). Subsequently, they were asked to carry out another session with the p-VE. The only difference is the questionnaire at the end of the session, which was tailored with designer practitioners in mind (see Figure 14).

5. Results of Experiment 1: preferences expressed by general participants

Experiment 1 drew 186 participants from five different countries. 55.7% of the participants were male. Most the participants were students 135 (72.58%), of which 8.6 % of them were design students, 28 (15.1%) were designer practitioners, and 23 (12.4%) had other occupations. The results from Experiment 1 are presented in the following five sub-sections.

5.1 Usability of p-VE

First, for the usability assessment, the experiment received 120 responses out of 186 participants (64.52%). A simple statistic is used to analyse the result and calculate the mean rating (mr) of the responses (Figure 9). Responding to the first question (Q1), 94 (78.33 %) participants agreed the application is easy to use (mr=2.41); 85 (70.83%) were satisfied with the support system (Q2, mr=1.87); 89 (74.17%) participants felt satisfied with the amount of time to complete the task (Q3, mr=2.27); 79 (65.83%) agreed the platform allowed them to express spaciousness adequately (Q4, mr= 1.40), 80 (66.67%) participants somewhat agreed the platform allowed them to express their preferences for the windows & ceiling type adequately (Q5, mr=1.42); 69 (57.5%) participants somewhat agreed the platform allowed them to express the Colour scheme adequately (Q6, mr= 0.71); and 86 (71.67%) participants agreed that platform can develop designer's awareness of users' visual preferences (Q7, mr=1.70). The usability result shows an improvement from the piloting test.

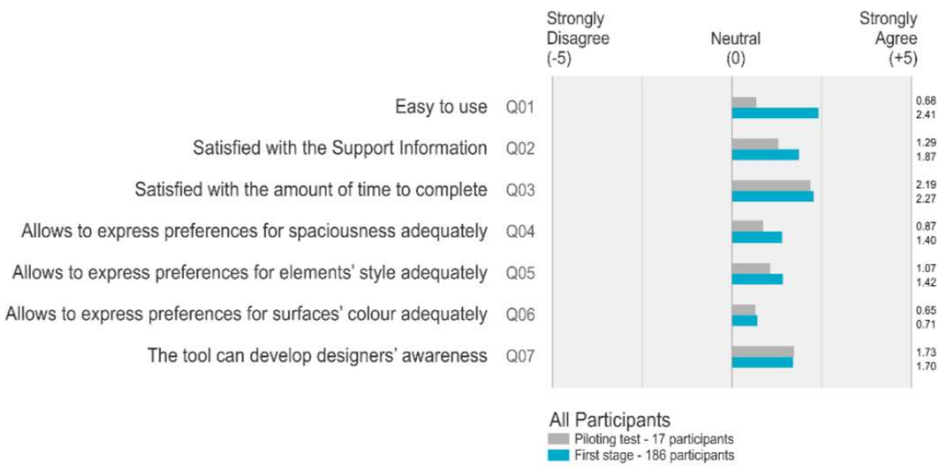


Figure 9. The Usability Assessment of p-VE in Experiment 1 compared to the Piloting Test

5.2. Confidence rating

For the Confidence Rating, 41 out of 185 participants (22.2%) felt 'Completely confident' during the experiment, 'Very confident' (30.3%, 56/185), and 'Confident' (38.9%, 72/185). Only 8.9% participants felt less confident, ranging from 'Somewhat confident' (3.8%, 7/185), 'Not very confident' (2.7%, 5/185), and 'Not confident at all' (2.2%, 4/185) (Figure 10).

Figure 10. Confidence rating of p-VE returned by the participants in Experiment 1

5.3. Surface colours for Wall, Ceiling, and Floor

For *wall surfaces*, the most preferred colours are Duckegg (8.14%), followed by White (6.4%), Blue (5.81%), Sky (5.23%) and Aqua (4.65%); none of these colours exceeded 10% of the total votes. The least preferred colours with no votes are Coral, Beige, Choc, and Grey. For *ceiling surfaces*, only one colour surpasses 10% vote, which is White (15.64%). Other colours worth mentioning are Blue (7.82%), and Breeze (5.59%). Duckegg (4.47%) and Green (3.34%) were among the top five. From all 48 colours, only Red did not receive any vote. For *floor surfaces*, White (10.56%) and Charcoal (10%) are two colours that surpassed 10% votes. Black received 6.67% votes. Another colour that within the top five are Beige and Slate. The colours not receiving any votes are Haze, Lilac, Pink, Yellow, Peach, and Coral (Figure 11).

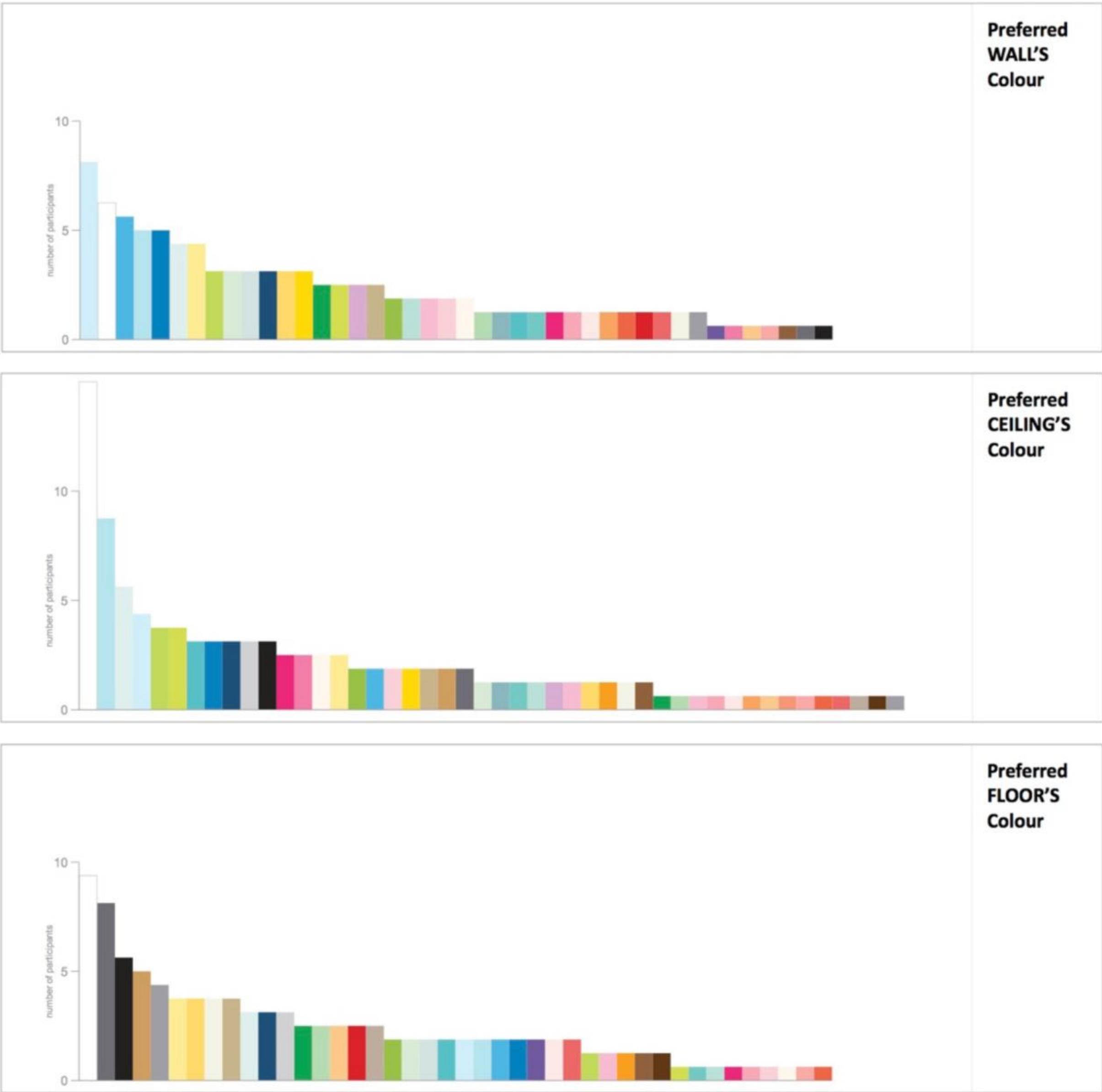


Figure 11. The colour preferences for Wall, Ceiling, and Floor surfaces collated from Experiment 1.

5.4. Window and Ceiling styles

Three *window* styles got more than 10% votes in which *Windows02* was the most preferred with 67 (36%) votes, followed by *Windows03* with 53 (28.5%) votes, and *Windows04* with 37 (19.9%) votes. The other three styles received significantly lower votes are *Windows05* receiving only 14 (7.5%) votes, *Windows01* 9 (4.8%) votes. Nine participants (3.2%) voted for the *No-Windows* option. The result from the *Ceiling* style shows *Ceiling03* as the most preferred with 44 (23.7%) votes, *Ceiling05* received 39 (21%) votes, *Ceiling04* is the third with 34 (18.3%) votes, *Ceiling02* received 24 (12.9%) votes, and *Ceiling01* voted by 13 (7%) participants (Figure 12).

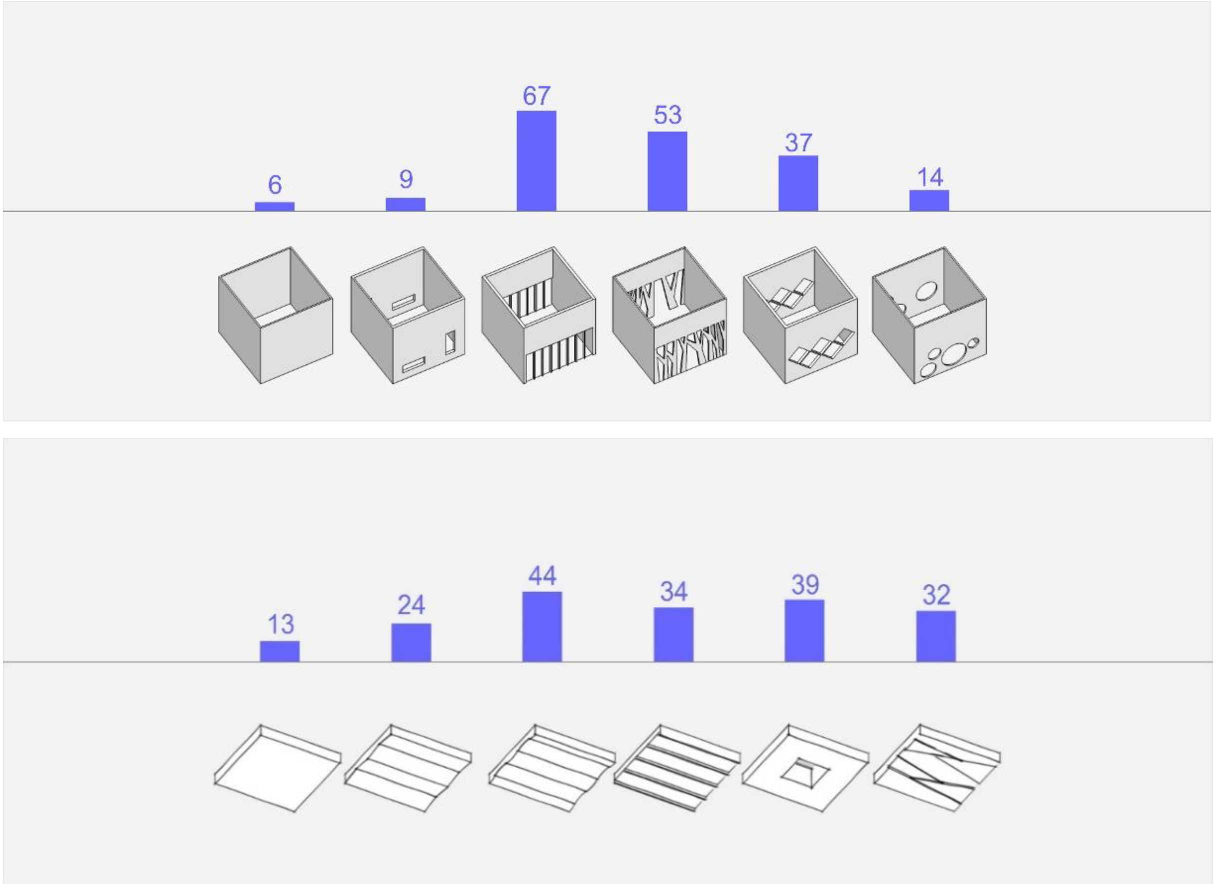


Figure 12. The window style (above) and ceiling style (bottom) preferences from Experiment 1.

5.5. Spatial dimensions

The *Spatial Dimension* consists of three properties, X and Y representing width and depth of the floor area and Z for the ceiling height. The range 8–8.995m is the most voted for X by 36 (19.35%) participants. The second is 16m that received 26 (13.98%) votes. The third is 11–11.995m by 23 (12.37%) participants and the fourth is 9–9.995m with 20 (10.75%) votes. Another range received more than 10% votes is the range 10–10.995m, which is on the fifth rank that preferred by 19 (10.75%) participants. The least preferred range is 2–2.995m.

Like the Length X preference, range 8–8.995m is also the most preferred depth for Length Y, favoured by 32 (17.20%) participants, and the second is 16m by 29 (15.59%) participants. The third is the range 9–9.995m by 27 (14.52%) votes and the fourth is range 10–10.995m by 23 (12.37%) participants. Another range received more than 10% is the range 12–12.995m with 21 (11.29%) votes. Three least preferred Y ranges are 2–2.995m, 3–3.995m, and 4–4.995m received no votes.

For the Ceiling Height Z, the top ranked range is 4–4.995m, which is preferred by nearly half of the population (49.46%) or 92 votes. The second ranked is 5–5.995m preferred by 45 (24.19%) participants. The rest of the classes received less than 10% votes, with the least preferred ceiling height 2–2.995m. Interestingly, the results of the floor area dimensions (Length X and Length Y) show a significant high number of votes going for the maximum length (16m), which are clearly off the decreasing trends from the peaks (most preferred ranges). However, this choice did not appear on the Ceiling Height Z result (Figure 13).

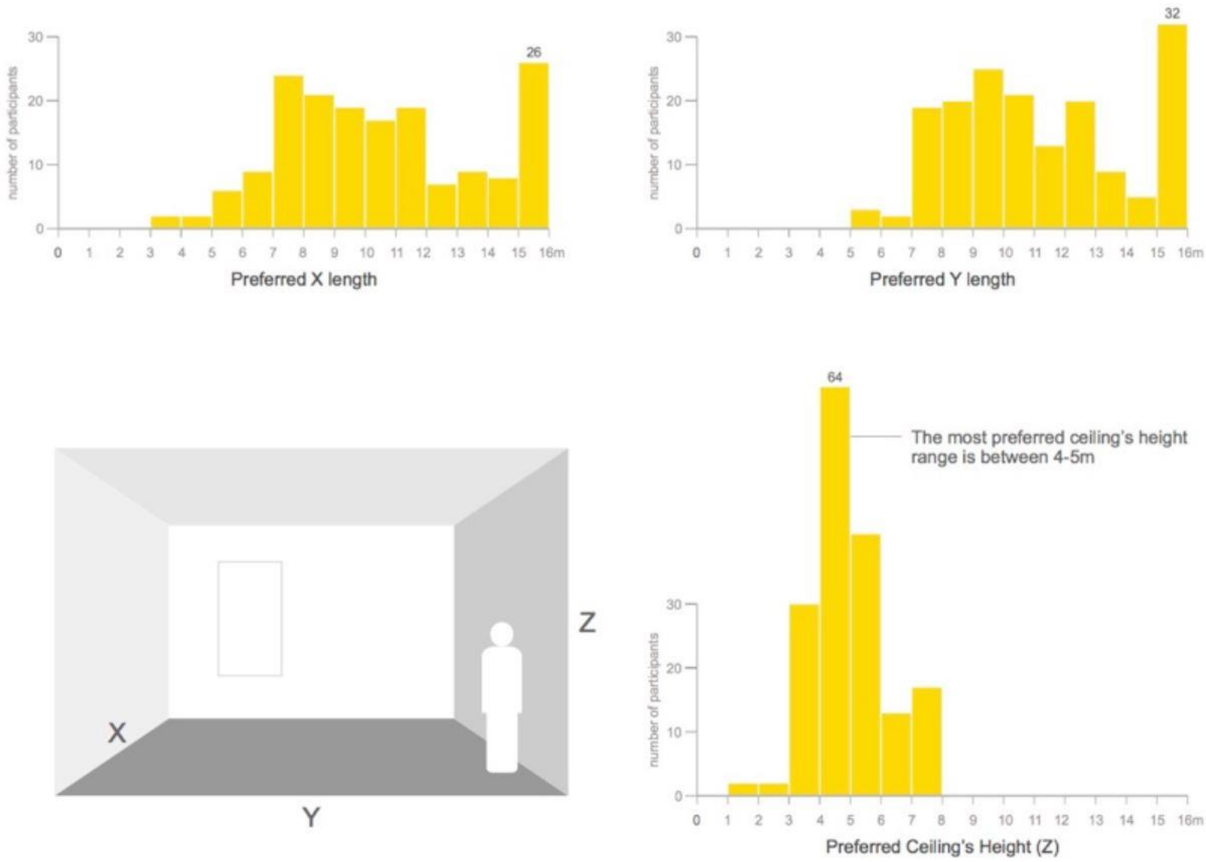


Figure 13. The preferences of spatial dimensions X, Y and Z collated from Experiment 1.

6. Results of Experiment 2: relationship to preferences

Eighteen professional designers from two different countries participated in Experiment 2. Eight of them have previously taken part in Experiment 1, hence were familiar with p-VE. The ten new recruits were asked to go through the Experiment 1 session first to familiarize themselves with the platform before joining the others to proceed with Experiment 2. The results of Experiment 2 are presented in the following two sub-sections.

6.1 Designers' responses to the VPS results collated from Experiment 1

The responses received show 16 (88.89%) participants strongly agreed that the visual analytics of Experiment 1 is easy to understand (Q1) with mr=3.55 (Figure 14). The designers also think that the results from Experiment 1 have influenced their choices/decisions made in Experiment 2: 14 (77.78%) agreed the influence of colour preferences (Q2, mr=2.27); 15 (83%) the spatial dimension preferences (Q3, mr=2.14); 14 (77.78%) the window's and ceiling's styles (Q4, mr=2.69). Fourteen (77.78%) designers agreed that the visual preferences analytics helped them to understand the users' characteristic (Q5, mr=2.89), and how the design should be developed (design direction, Q6, mr=2.56). Regarding restriction on design creativity, 13 (72.22%) designers felt that the overall influence of the VPS data is somehow restrictive (Q7, mr=1.81). Despite 12 designers (66.67%) agreed that they would regard the VPS data as guidance (Q8, mr=2.04), nine designers (50%) agreed that they could take a different direction in the design development, against three (16.67%) who disagreed, while six (33.33%) participants were undecided (mr=1.66).

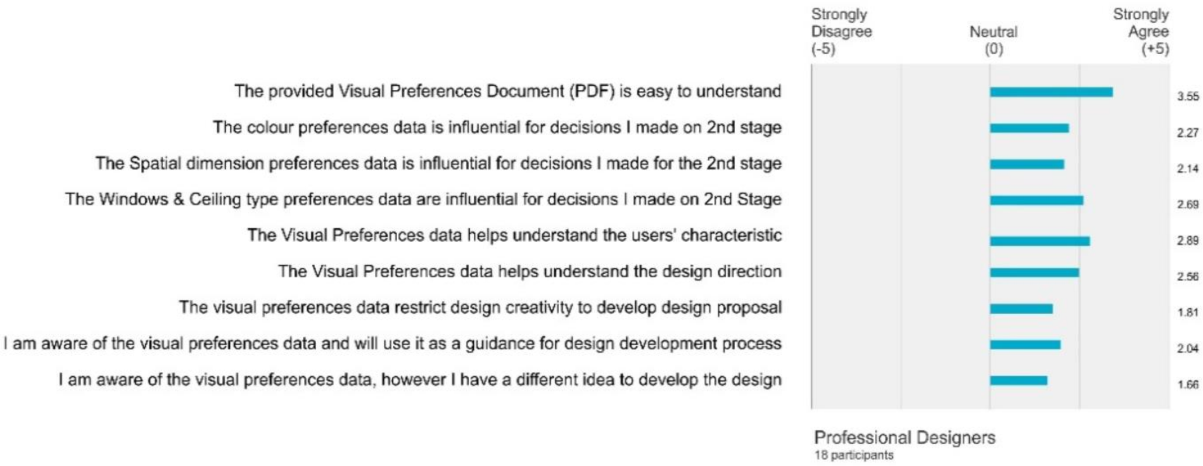


Figure 14. The responses returned by the 18 design practitioners in Experiment 2

6.2 Designers' 'positional changes' tracked between Experiment 1 and 2

The data generated by participants allow for inspection by the researchers to identify if design changes occurred between both stages. This could reveal more details about how the VPS analytics has affected design decisions made by the practitioners. Figure 15 shows three examples of pairing the learning space models produced by Designer 08, 14, 11 along with their responses to Q2 (influence of colour preferences), Q3 (influence of spatial dimension preferences), and Q4 (influence of window & ceiling style preferences).

Based on all the preferences expressed in both experiments, DS08 is an example showing that the design changes made in Experiment 2 was influenced by being 'in-favour' of the Experiment 1 result (i.e., significant changes made to be in-favour of the visual preferences expressed by most participants). DS14 is an example of being in a 'neutral' position (i.e., few and insignificant changes made between Experiment 1&2). DS11 is an example showing design changes influenced by being ‘not in of favour of’ the Experiment 1 result (i.e., significant changes made to be not in-favour of the visual preferences expressed by most participants). Under an overall positional grouping scheme, among the 18 design practitioners, ten (55.6%) were ‘not in-favour’, three (16.7%) were ‘neutral’, and five (27.7%) were ‘in-favour’. Table 2 shows a more detailed positional distribution of Experiment 2 against each visual attribute.

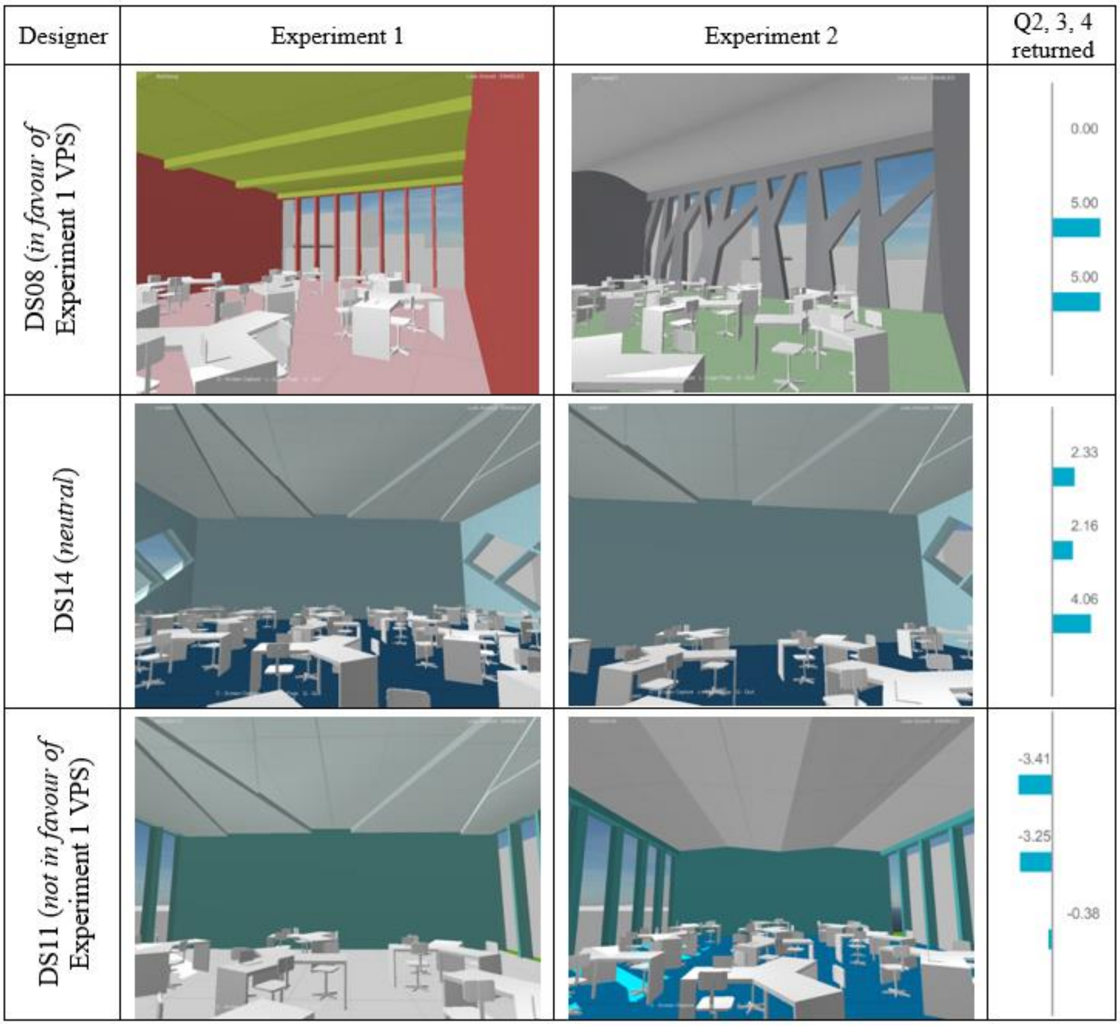


Figure 15. Examples of pairing the learning spaces created by some selected design practitioners in Experiment 1 and Experiment 2 (with Q2, Q3, Q4 returned in Experiment 2)

Table 2. The ‘positional change’ result of Experiment 2 under each visual preference variable

Visual Variables	**Positional Change**		
	‘Not-in-favour’	*‘Neutral’*	*‘Favour’*
Wall Colour	6 (33.3%)	5 (27.8%)	7 (38.9%)
Ceiling Colour	3 (16.7%)	7 (38.9%)	8 (44.4%)

Floor Colour	5 (27.8%)	8 (44.4%)	5 (27.8%)
Floor Length X	11 (61.1%)	2 (11.1%)	5 (27.8%)
Floor Length Y	9 (50.0%)	2 (11.1%)	7 (38.9%)
Ceiling Height	6 (33.3%)	10 (55.6%)	2 (11.1%)
Window Style	3 (16.7%)	13 (72.2%)	2 (11.1%)
Ceiling Style	3 (16.7%)	11 (61.1%)	4 (22.2%)
Positional Sums:	46 (31.9%)	58 (40.2%)	40 (27.9%)

7. Discussion

Usability of p-VE for L-VPS in learning space design

In terms of scale of participation, Experiment 1 has shown usability of the proposed method and tool. Compared to the initial pilot test (19 participants), Experiment 1 received nearly ten times more participants (186) from various countries. The only technical problem encountered was the sudden change of the Web technologies used in the experiment, whereby popular Web browsers were withdrawing support for the web technology used by p-VE. This led to some participants' having problems of installing the Unity player required to run p-VE. Therefore, in future development of p-VE, it will be necessary to keep pace with the changing technologies to sustain large-scale participation by anyone anytime anywhere.

Based on the participants' responses collated in Experiment 1, the highest mean rating (mr=2.41) received was for the question that p-VE is easy to use (agreed by 78.33% participants). The second highest is regarding the satisfaction on the time spent, and the third is the satisfaction of the supportive information provided on the platform. These results show that a high proportion of the participants were reasonably satisfied with the overall usability of p-VE. However, p-VE's facility to support participants' choosing surface colours received the lowest rating (mr=0.71), followed by spatial dimensions (mr=1.40), and the window/ceiling style (mr=1.42). Despite the current limitations on the scope of parametric modelling, a high percentage of the participants (91.4%) felt confident about using p-VE to express their visual preferences, with 52.2% rated highly confident. Nevertheless, p-VE as an L-VPS prototype platform can be further improved and developed.

Influences of the VPS outcome on design practitioners' positional changes

In the Experiment 2, a high percentage of the design practitioners (88.89%) agreed that the visual analytics from Experiment 1 was easy to understand (mr=3.55). They also generally agreed that knowing the results from Experiment 1 has influenced their design decision during

Experiment 2. It is noticeable that 72.22% of the designers thought that the VPS data posing some kind of restriction on design creativity. In analyzing the virtual models produced by the design practitioners and their replies to the questionnaire, a schema of 'positional changes' was proposed in terms of '*in-favour of*', '*neutral'*, and '*not in-favour of*' to interpret how the influences might have been manifested. Firstly, the positional outcome summarised in Table 2 shows that design decisions were made under the influence of the VPS analytics either 'in-favour of' (27.9%), or 'not in-favour of' (31.9%). The 'neutral' position (with the highest positional sum of 40.2%) could indicate that the design practitioners were already in agreement with the visual attributes preferred by most participants. Secondly, the graphical outputs assembled in Figure 15 shows some samples of differences between Experiment 1 and 2 as returned by those selected design practitioners. In comparison, the case of '*in-favour of*' (DS08) shows the widest range of changes in the choices of visual attributes, while '*neutral'* (DS14) showing the least changes, and '*not in-favour of*' (DS11) showing a range of changes somewhere in between. DS11 decided to change the ceiling pattern and floor colour in Experiment 2 while declaring not in-favor of the visual preferences expressed by participants in Experiment 1. Therefore, the '*neutral'* position is least influenced; '*in-favor of*' and '*not in-favour of*' positions may be equally influenced but in different directions (senses). Thirdly, against each visual attribute, the highest 'not in-favour' (61.1%) appears in Floor Length X, the highest 'neutral' (72.2%) in Window Style, while the highest 'favour' (44.4%) appears in Ceiling Colour. These visual attribute-specific VPS results indicate where and how the general participants may differ from the design practitioners.

From L-VPS to co-design: A proposed model of user-designer partnership

Given the data collated from both experiments, it is possible to generate 'synthetic' models by combining rankings of visual preferences with the participants' background information provided. Figure 16 shows four examples of such models amalgamated on p-VE. This initial attempt at generating synthetic models from the participatory process demonstrates the feasibility of turning a research L-VPS tool into a potentially creative co-design platform accessible to both public and design practitioners.

A model of user-designer partnership can be proposed at the early stage of design, in which a generic virtual model of learning space design is introduced and used through various cycles, reflecting dynamic relationships between prospective users and design practitioners (Figure 17). The partnership can involve parties from the system developer, architectural design practitioners, user community who share interests in a design domain such as learning space design. As revealed from both experiments, the challenge seems to be the mind-set of the design practitioners to be able to recognise and co-design with other parties as creative partners.

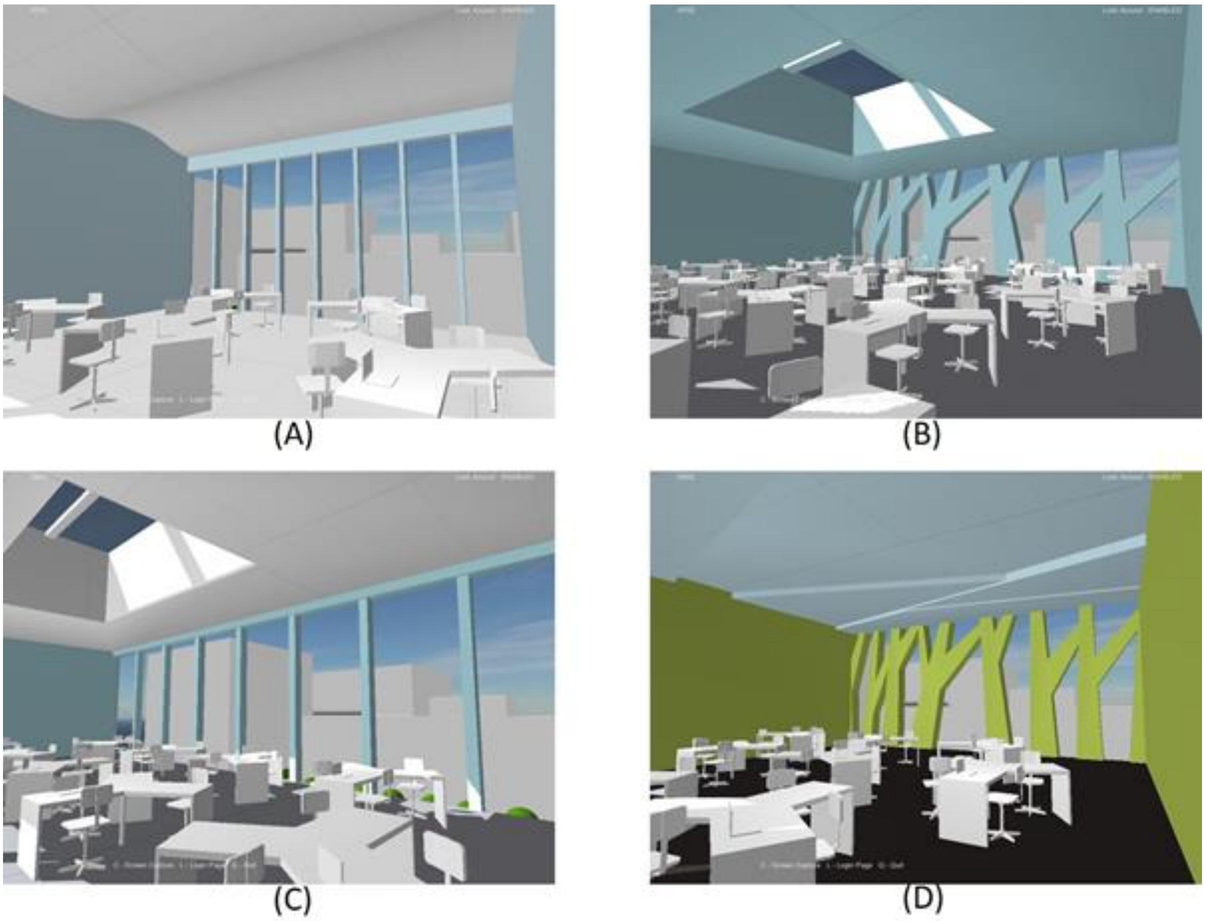


Figure 16. Views of synthetic learning space models ‘amalgamated’ from Experiment 1 & 2: (A) Learning space collated with most preferred visual attributes by all participants; (B) Learning space collated with 2nd-ranked visual attributes by all participants; (C) Learning space collated with most preferred visual attributes by design practitioners; (D) Learning space collated with 2nd-ranked visual attributes by design practitioners

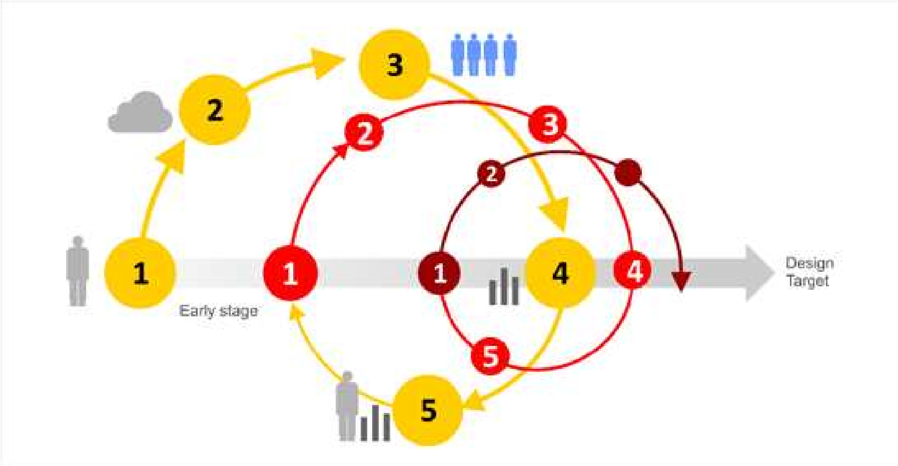


Figure 17. A proposed model of user-designer partnership through cycles of L-VPS through user interaction with a parametric modelling approach.

8. Conclusions

In this study, the influences of visual preference expressed by participants on early stage of learning space design were explored using an interactive parametric modelling approach. To extend the existing visual preference survey (VPS) methods, a parametric virtual environment (p-VE) was developed utilising Web-based technologies to enable wider participation by anyone anywhere anytime. At present, the p-VE as prototype is designed for conducting large-scale VPS (L-VPS) in a context-free manner, featuring only a limited range of visual factors in learning spaces design. Nonetheless, the generic and less detailed interior and exterior information appears sufficient for its intended use at the early design stage. One of the key findings of the study is identification of the differences in visual preferences of a generic learning space between general users and design practitioners and the influences of such information on the design process as manifested by the design practitioners' positional changes.

The two-stage experiment has tested the efficacy of p-VE to enable a large number of participants to engage with expressing visual preferences in learning space design. By altering the various parameters on p-VE, participants in effect create 3D virtual artefacts as expressions of their visual preferences. The approach received positive responses from the participants, as they felt moderately supported in expressing their visual preferences regardless their backgrounds. The experiment shows that the current design of the p-VE for L-VPS can support design practitioners' better understanding of visual preference of a population. The Web-based interactive 3D parametric modelling approach achieves broader demographic reach and economic resolution of visual attributes of learning space. Our further development of p-VE will aim to generate synthetic on-demand models according to preferences expressed by participants in real-time. The system-assembled models can show a population's visual preferences in learning space design ranked according specific visual attributes or as a whole.

Here we presume a social-ethical ground that learning space design should consider users' visual preferences. Design practitioners may still have their design decisions made not in-favour of preferences expressed by large-scale VPS survey. However, in our view, this is advancement in learning space design if design practitioners can be made aware of users' visual preferences at the inception stage. Nagamachi advocates that a design should comprise 60-70% in favour of the users' needs, and leave the 30-40% to the designer (Nagamachi & Lokman 2010). We develop a digital method and tool for launching large-scale visual preference (L-VPS) survey enabling anyone interested in learning landscapes to participate anywhere anytime. Visual analytics can be generated from the L-VPS and made accessible to design practitioners. For further studies, we will investigate (1) how the experiment with a generic learning space can be extended to a site-specific context and its implication of complexity, (2) more efficient algorithms for generating real-time on-demand visual analytics of expressed visual preferences accessible to both users and designers of learning spaces.

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