Expressing Visual Preferences Through Interactive Parametric Virtual Environment to Inform Early Stage of Learning Space Design

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“Have no fear of perfection, you’ll never reach it.”
~ Salvador Dali

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Abstract

The design of learning spaces is characterised as a social-creative process in which designers initiate a partnership with prospective users to identify the space's attributes that may support learning activities. This thesis investigated the efficacy of a method on enabling such a large-scale partnership in the early stage of a design process. The survey method is designed to initiate participation from anyone anytime anywhere, and on the other hand, to collate the visual preferences expressed as user data for professional designers to work with iteratively. An interactive online 3-D Parametric Virtual Environment platform was developed to implement the survey method and was used in carrying out a two-stage experiment. During the first-stage experiment, 186 multi-national participants accessed the 3-D platform to express their visual preferences through a set of parameters altering how a learning space may look like preferably. The visual preferences collated from the first stage were analysed and presented as visual analytics to participants in the second stage in which 18 design practitioners took part. The experiment reveals how the participants perceive-usability of the proposed method and how the design practitioners responded to the visual preferences collected through it.

Publication Note

Some of the works in this thesis have been published prior to thesis submission in:

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Chapter 01
Introduction

1.1. Background

In recent educational architectural planning and design research, the concepts and built examples of Learning Landscapes have emerged as a new paradigm underpinning new developments of university campuses, buildings and spaces for 21st century higher education (Boys 2010). It is argued that the design and use of university learning spaces need to be articulated by more than just programmatic buildings with predefined functional types. The Information Commons at the University of Sheffield is a case in point where it presents a distinctive departure from an archetypal conventional library design (M. Lewis 2010). The Augustine House at the Canterbury Christ Church University is another example demonstrating that the provision of pedagogical affordance to achieve user-centric performances as learning landscapes were at the core of the project (Peng 2011).

The importance of involving student for 21st learning spaces design has been pointed out on many occasions, either to involve them in re-arranging the space (Jisc 2006), or in the design process (Woolner 2010, 58). Simply on the basis of their better knowledge of the learning environment, and the activities took place there. Although there are already groups that take the learner's participation seriously, their inclusion in the design process of learning spaces has rarely been heard. As researchers suggest (Scott 1993; Park and Guerin 2002; Ham and Guerin 2004), designers are required to develop the knowledge of the users' needs or actively involving them in the design process. Many believed that involving a large-scale of users also means generating more potential design solutions (Sanders and Stappers 2012; Barisano 2013) but mostly avoided due to its complication with cost, efficiency. In some cases, the students can also come from various places worldwide with a different culture i.e. culture and language barrier, which could hinder the effort. In the book *Emotional Design,* Norman noted one radical idea brought up by Harrison and Douris (1996):

"A Space can only be made into a place by its occupants.
The best that the designer can do is put the tools into their hands."

This study investigates how the interiors of a new learning landscape can be planned and designed with users in mind, and where the visual preferences expressed by a large number of prospective users are collated at the early stage of the design process. The challenge here is the size of the potential user population, which will daily inhabit the learning landscapes. With the belief to hand the tools into the users', which could be hundreds or thousands in number. How can the designer provide the tool?

Knowing the users' (i.e. students, staff, lecturers) preferences and tastes in design aesthetics are a necessity for developing learning spaces that are motivating and supportive for the learning activity. However, they can be hard to determine. What "motivating" or "vibrant" means to one person may mean something different to another. Language alone cannot represent all the nuances of the experiences. Therefore, involving a large number of users can be extremely complicated.

Since design aesthetic is closely related to a visual stimulus, a method that enables the expression of preferences in a visual medium should be easier to comprehend compared to other methods (i.e. verbal). Especially when dealing with potentially a large population of users with various backgrounds and skills.

1.2. Problems Statements

Most of the existing visual preference survey methods are physical-based, constraining time, space and the size of user participation in the planning and design processes. By adopting a digital approach, this study will investigate the efficacy of an experimental visual preference survey method that could initiate large-scale participation from members of the public as users and/or designers of learning spaces in expressing their visual preferences anytime, anywhere. The method used in this study is also required to collate the participant visual preferences as essential user data for designers to work with at the early stages of design. The research hypothesis of the large-scale, digital-based, visual preference survey method is twofold:

- it will facilitate effective identification of primary visual attributes of learning spaces that users are most conscious, of or concerned with; and
- if made accessible to design practitioners, the more detailed visual preference information collated can play a significant role in the early design stage, as reflective practice.

User preferences can vary depending on demographic conditions, as well as other factors (Park and Guerin 2002; Ham and Guerin 2004). Meanwhile, large-scale user participation in the early stages of the design process is usually avoided due to various reasons, such as efficiency, which can lead the designers to work based on their own presumptions of user' need. A dynamic, flexible, and timely method to collect and present the data is required to assist the designers. Therefore, this study proposes a method and tool to enable large-scale user' participation in the early stages, to express visual preferences for learning space.

Designers are well known for their creativity in solving design problems, and generally, they have been regarded as individuals who can think outside of the box. However, like other professionals, some times they do have communication barriers with the user during the design process. Chifter and Dong (2008) infer the problem could arise due to differences in characteristics (i.e. training, knowledge, etc.), they suggest that designers need to make their product more intuitive and easy to understand to the user. Considering the designer and user relationship this study will also investigate whether the participants with design and non-design background have significant differences in preferences for learning spaces.

In this research, we presume on ethical grounds that the main goal of designing learning spaces (for a higher education setting in this case) should be consistent with an understanding of learner' visual preferences. No claim is made here that learning spaces (landscapes) designed with user visual preferences in mind will deliver better learning performances, which is subject to further research.

1.3. Research Questions

To address the problems statements, this study focuses on the following questions:
How can a large number of participants with various backgrounds be facilitated in the early stages of the design development process to express visual preferences for learning spaces?

a. How can a large number of participants with various backgrounds be facilitated in the early stages of the design development process to express visual preferences for learning spaces?
b. How do the proposed methods show the visual preferences for learning spaces?
c. How different are the preferences of the participants with design and non-design background through the proposed method?
d. How the professional designer's rate the proposed method, and respond to the visual-preferences results gathered from the proposed instrument?

1.4. Aims and Objectives

The research aims to achieve the following:

a. To propose and investigate a feasible method and a tool to facilitate a diverse population from various places to express visual preferences of learning spaces at the early stages of the design development process.
b. To investigate how the diverse population may differ in visual preferences of learning space through the proposed method and tool.

More specifically, the research has the following objectives:

a. To design, implement and test a method to facilitate a diverse population in expressing visual preferences in the early stages of learning space design.
b. To conduct experiments, assess the results and investigate the relationship between the participant's groups.
c. To assess the professional designer's valuation on the proposed method and tool, and their responses to the participants’ result.

1.5. Research Methods

The study carried out descriptive research in order to answer the research question. Bhat (n.d.) defines the descriptive research as a research method that describes the characteristic of the population or phenomenon being studied. One of the characteristics is the quantitative research method to collect quantifiable information for statistical analysis of the population sample, which is appropriate for visual preferences survey as this study.

This study is divided into two parts: The first part is focussing on the design, implementation, and the second part is a two-stages experiment to test the method in a real scenario to collect expressed visual preferences. Each part of the study involves the participants both as the population that influence the design direction and as the population being studied.

a. The Design and Implementation part will design and develop the instrument, consisted of:
    - A preliminary study is the preparation stage for the implementation stage.
    - Development is the implementation of the method, guided by the preliminary study results.
    - A piloting test is a mini-experiment to test the application. The feedback gathered from the test then used to make a revision.
b. The two-stage experiment consisted of:
    - The first stage is the main experiment to collect the data from large-scale participants and conduct a usability test.
    - The second stage, to collect data from the designers

1.6. Thesis Outline

In this study, the author divides the thesis into 10 chapters, which reflect the work done from the start of the research.

Chapter 01 Introduction

This chapter describes the background of the study, problems statements, research questions, aims and objectives, research methods and thesis outline.

Chapter 02 Literature Review

This chapter discusses the relevant literature regarding visual preferences, user participation, review of previous methods, the learning spaces appearance and recommendations.

Chapter 03 Research Methodology

This chapter discusses the methods used in this study to answer the research questions. The discussion starts from a preliminary study and its development, a piloting test, the two-stage experiment, Sampling and Data Analysis.

Chapter 04 Design and Implementation

This chapter presents the design of the system and the implementation process.

Chapter 05 The Experiment Design

This chapter presents the steps of the experiment used in the study.

Chapter 06 The First-Stage Results

In this chapter, the data gathered from the First stage experiment is processed and revealed, which consists of the usability test, the visual variables of learning spaces, and the design and non-design background comparison results.

Chapter 07 The Second-stage Results

In this chapter, the data gathered from the Second stage experiment is processed and revealed, which consists of the questionnaire results, and the comparison of the scenes generated in both stages of the experiments by the professional designers.

Chapter 08 Findings and Discussion

This chapter discusses and analyses the results revealed in Chapter 07 and Chapter 08, especially in terms of feasibility and usability of the platform, the visual preferences of learning spaces, the design and non-design background comparison, and the professional designer responses.

Chapter 09 Conclusion and Recommendations

The chapter presents the conclusions from what has been learned in the previous chapters, as well as discussing the limitations of the study, and recommendations and suggestions for further research.

Chapter 02
Literature Review

2.1. Visual Preferences

Im (1984) defined a visual preference for a place as an individual's or a group's like or dislike for the visual appearance of a place, which can be influenced by several physical variables, such as texture, colour and shape of space components, and also ratios of space dimensions. If other stimulations (i.e. noise, humidity) are not at a disturbing level, visual preferences can be very important in the aesthetic-visual quality appraisal of enclosed spaces. Scherer (2005) posits preferences as a relatively stable judgement, in the sense of liking and disliking a stimulus, determined by *collative properties* i.e. narrow-wide, short-tall. Since the expression of visual preference can either verbal or nonverbal, it is also a popular choice among studies where the subjects are unable to express their preference in spoken language, relying on them to 'show' rather than to 'tell'. For example is to investigate Bumble Bee's preference of floral colour (Gumbert 2000), or Infant's colour preferences in the interior environment (Read and Upington 2009).

Berlyne's *Arousal theory* is fundamental in aesthetical evaluation. The theory postulates that pleasure is related to observer arousal levels, which are affected by environmental stimulus (Berlyne 1971). Appleton's *prospect-refuge* theory builds on habitat theory, which links aesthetic pleasure to the experience of the landscape to satisfy basic human needs. Appleton argues that seeing without being seen is fundamental to satisfy basic biological needs. Kaplan's *information model* offers a conceptual framework to explain preferences, which assumes that people prefer settings in which they are likely to survive. People's cognitive impressions appear to influence preferences for specific environments. The four determinants suggested by Kaplan and Kaplan (Kaplan and Wendt 1972) are: a) Coherence i.e. how easy a setting can be organised cognitively, b) Complexity i.e. the perceived capacity of the setting to occupy interest and stimulate activity, c) Legibility i.e. perceived ease of use, d) Mystery i.e. the perception that entering a setting would lead to increased learning, interaction, or interest.

2.1.1. Preferences of Interior Spaces

Inspired by Kaplan's work, Scott (1993) conducted a study linking aesthetical evaluation to the cognitive process by identifying visual attributes of commercial indoor environments (offices, hotels, universities) that underlie preference. To do that, Scott grouped images by their similarity in ratings, and they were subsequently named in accordance with common design attributes. The experiment involved 309 college students rating 80 slides of interior space. Black and white photographs were used. Scott reasoning the inconsistency of colour reproduction in photographs can affect preferences.

Four experts involved in the study identified a series of individual design/visual variables that construct the visual attributes or characteristics of the visual environment. They are:

1. Geometric shape/sense of shape i.e. the perceived form and shape of the elements within the space, such as the enclosures, the openings, or the furniture. The geometric shape is one of the most important determinants that influence occupant's perception of the quality of the interior spaces.
2. Spaciousness i.e. a multi-variable visual factor influenced by floor area, ceiling height, the degree of enclosure, or the density of interior elements. The degree of the enclosure is the perceived rigidity of the enclosure to the occupants, which is influenced by the openness. The lower the degree of enclosure, the more transparent the enclosure seems. This can be achieved by having large windows and glass materials. The density of interior elements is the number and proximity of furniture and other objects within the interior space. Another important factor that can dramatically change the perceived spaciousness is the crowds
3. Directional Emphasis i.e. the ease of finding your way and direction in the interior space. For example, the ability to quickly find the fire exits whenever required. On the urban scale, directional emphasis can be assisted by the existence of landmarks in the city. In an interior space, signs and symbols can be very effective in strengthening the directional emphasis.

4. Spatial organization i.e. the arrangement of the elements within the space. In multi-functional spaces, like the Information Commons, an open setting space can contain various activity groups i.e. the library, study and discussion spaces, the I.T. and so on.
5. The Complexity of Visual field i.e. the number and variety of elements; either variety in function, shape, form, or colour. As mentioned above, complexity has been linked to preferences in Kaplan's study.
6. Surface Texture and Pattern i.e. texture and pattern are related to the finishing techniques and materials used on the surfaces i.e. smooth, wooden, tile etc.
7. Surface Value i.e. the lightness or darkness of colour on the surface.
8. Lighting Composition and type i.e. lighting composition relates to the placement and arrangement of the light bulbs. Lighting type is related to the specification of the light source itself, such as the light distribution (i.e. spotlight, ominous) and temperature i.e. warm, cold etc.
9. The Presence of windows, plants and natural light i.e. the importance of the presence of windows and natural light has been discussed in numerous literature (Tanner 2000; Harrop and Turpin 2013; Küller and Lindsten 1992). In most cases, the presence of windows also closely relates to the presence of natural light. There are also various articles discussing the benefit of the presence of plants in learning spaces (Woolner 2010; Beckers, van der Voordt, and Dewulf 2016).
10. The presence of aesthetic / art objects. For example, poster, painting, or sculpture. This variable was derived from another study (Campbell 1979), where the researcher found a positive effect on the participants in the office environment.

Scott insists that the knowledge of visual attributes underlying people's environmental preferences can assist Interior designers and architects in designing aesthetically pleasing spaces conducive to positive attitudes, behaviour and wellbeing. Knowledge of the users' visual preferences can also be about avoiding visual properties that could cause discomfort to the occupants, which in turn can affect mood and motivation (Boyce 2003). It could be the light conditions or the use of colour, that can be sensitive for different personalities and cultures.

2.1.2. Preferences Link to Performance

As previously mentioned, Jisc suggests the design of learning space is expected to support and motivate the learner. Can the fulfilment of the learner's visual preferences lead to motivation and then performance? Bross and Jackson (Bross and Jackson 1981) conducted a study on girls in grades 7-9 which found that the participants made fewer errors when working in cubicles painted in their preferred colour, while time to complete tasks decreased. While Tanner (2000) found a correlation between student performance and design factors relevant to the school environment. However, Bailey (1993) carried out a study (of computer interface designs) to investigate the link between preference to performance concluded that preference does not always lead to performance.

Arousal theory, initiated by Berlyne, also offers an explanation regarding the connection of preferences to performance. He considered preferences to be a prototypical example of explorative behaviour, which allows the establishment of a link between stimulus patterns and behaviour (Ute 2002). Furthermore, he posits arousal as at its best and most effective when at a moderate level, and when influenced by the complexity and novelty of the arousing object. Based on Berlyne's theory, Yerkes and Dodson developed an empirical relationship linking arousal level and performance. The principle proposes that performance for a difficult task increases with arousal level until it starts to decrease at the point when the arousal level is too high. For a simple task, the performance will peak at a certain level *(Figure 1)*.

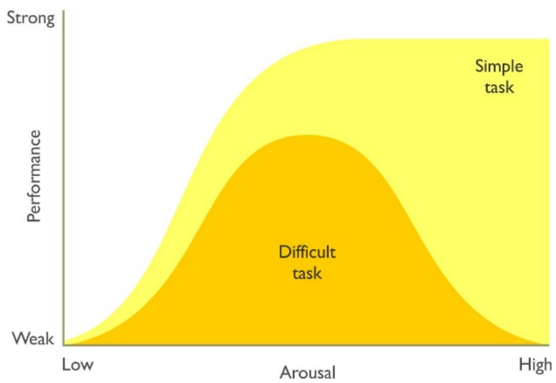


Figure 1. Diagram show relationship linking arousal level (motivation) and performance (source: Diamond et al. 2007)

2.1.3. Visual Preferences Survey

Anton Nelessen developed a Visual Preference Survey (VPS) in the late 1970s, aimed at obtaining public feedback regarding the visual quality of the environment. Initially developed to assess the urban environment, the VPS method gained popularity and has been applied in other design areas such as landscape, architecture, product design, and much more. The method comprises the use of a set of images by which the participants are required to choose the preferred one or rate them. In one of the surveys, Nelessen interacted with the residents of Metuchen (New Jersey, US), to look at and rank 320 slides. The aim was to survey a consensus regarding the local taste in the area. Over time, the VPS has become established as a method to obtain public responses regarding visual qualities in both research and professional uses (Times Special To The New York and Times 1989). The main advantage of the VPS is its accessibility, in a way it is easy to develop, easy to understand, and can be made accessible from different locations through the Internet. Since then various methods adopting the VPS has been widely practised assisting designers to develop various products, ranged from product design to the urban landscape. For example, the City of Burlington conducted a Visual Preference Survey among the citizens from September to December 2014, in which 131 participants responded to choose one of four photographs.

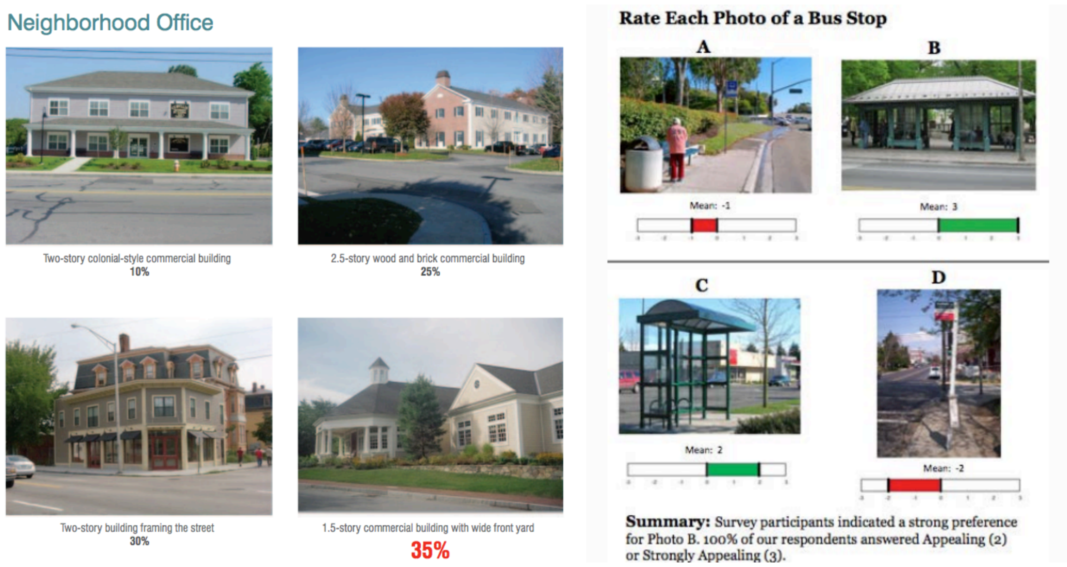


Figure 2. Making Choice (left) and Rating (right)
(Source: VISUAL PREFERENCE SURVEY RESULTS, 2014)

Expressing Preferences

There are three eliciting methods that commonly employed in a Visual Preference Survey (Huber, Ariely, and Fischer 2002), each has its own advantages:

a) The choice is eliciting method require the respondent to choose among alternatives. Making a choice method is perceived as the most realistic task and the one about which people feel most confident *(Figure 2 (left))*.

b) Rating is eliciting methods require the participants to rate the individual alternatives. It has been perceived as quick, robust at following known values, and perceived as an easy task by respondents *(Figure 2 (right))*.

c) Matching takes the most time and most difficult, it shows minimal biases. Rather than chose or rate among images/scenes, the agent is required to create an 'ideal' image/scene. An example of this method in a study on the construct of Masculine Identity, a library of texts regarding the characteristic of 'ideal' mates (boyfriends or husbands) were collected from Playboy Magazines' Centrefolds from 1954 to 1999, and then used by respondents to construct their perception of masculinity (Beggan and Allison 2001).

Studies in the area of judgement making have built evidence that people construct their preferences upon the revelation of the requirements set up by the task, consequently, different elicitation task evokes different preferences (Task Bias).

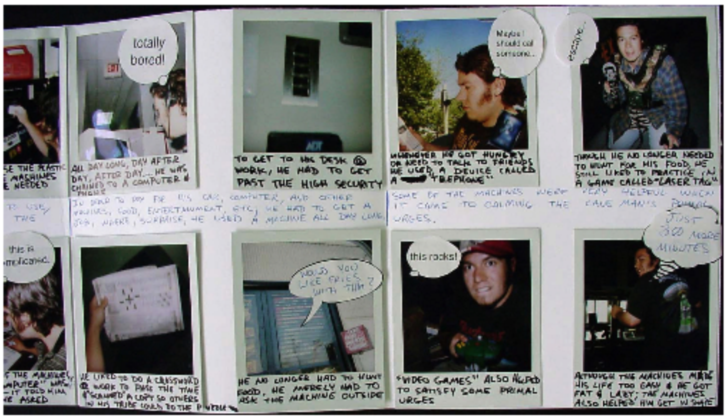


Figure 3. Tools for Storytelling 'Tell us a story about your life with consumer products at home' (source: Stappers and Sanders, 2003)

Encouraging the participants to express visual preferences also the main activity of the *Generative Tool* by involving the users in the early stages of design processes predominantly use visual language. *Generative tools* are initiated by *SonicRim*, which asked the participants to express aspects of their life and situation using a set of words and images. Using the given 'tool', the participants then created a collage, which was used by the designers for inspiration (Beggan and Allison 2001). Some suggest that people are creative in a way in which they can solve everyday problems, and share a similar dream to make life better for themselves and the community (Stappers and Sanders 2004). By involving the users in the early stages, the tool aimed to offer solutions to the overwhelming problems that usually emerge at the fuzzy front-end period before entering the formal design process. The tool itself has various implementations, either using the digital medium, or paper and pencil *(Figure 3)*. One of the characteristics is the simplicity of the task, which is usually asked for in a simple sentence.

One exceptional project in this area probably a platform by Mitsuo Nagamachi, called HULIS. Nagamacy is the founder of *Kansei* engineering (a user-centred product development method) who initiated an artificial intelligence system called HULIS (Human Living System), which has been pre-programmed to translate user affective words into design visualisations *(Figure 4).* The system consists of seven parts: 1) appearance, 2) structure, 3) entrance, 4) Japanese-style room, 5) Western-style room, 6) kitchen and 7) bathroom. The system requires the users to express their preferences through emotional words, whereby HULIS translates them into visual representations (Nagamachi and Lokman 2010). The system received an award in 1985 for its innovative approach.

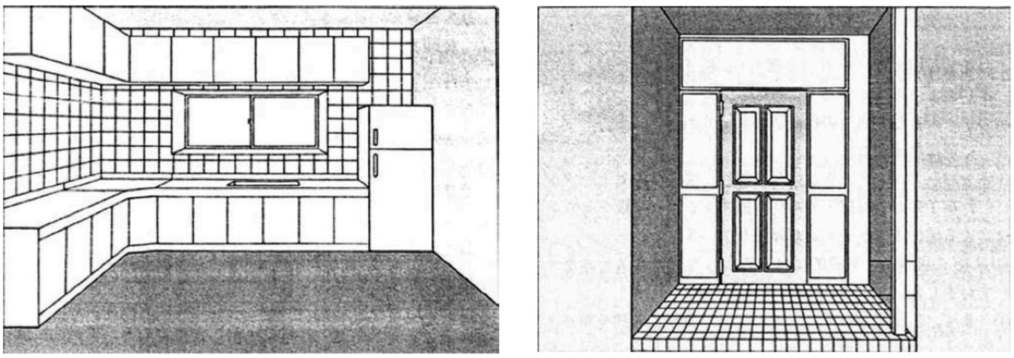


Figure 4. Examples of HULIS output
(source: Nagamachi and Lokman 2010)

In terms of the number of user involvements, HULIS is not aimed at large-scale involvement. However, it is at work in the early stages of the design process, where no design proposal has yet been produced. In this case, the system generates a visual brief to assist the designer by translating emotive words into visual representations, whereby it addresses the issue with the user and designer communication.

Presenting Visual Preferences Survey Results

In order to produce an impactful report, a clear and concise report must be produced with adequate information for the reader to comprehend. There are various methods to present the result of a Visual Preference Survey, depend on who will access the report, either it is the public, the planner, the architect, or the decision-maker. Typically using descriptive statistic to find the mode, mean, or percentage, and to incorporate rating system to show negative, positive, or neutral tendency whenever required ("The Visual Preference Survey (VPS)" n.d.). The City of Burlington published a PDF report accessed through the website used descriptive statistic showing the percentage distribution of the photographs as shown in Figure 5. For research that needs reliabilities from the data set, few more tests are usually conducted to test the data consistency.

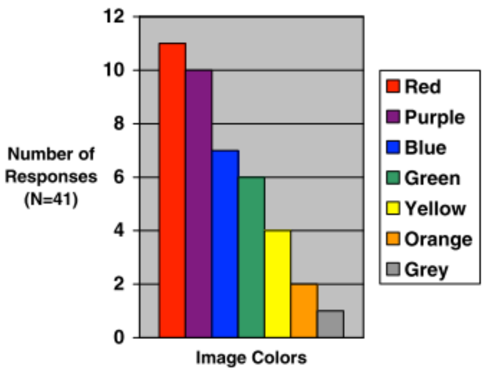


Figure 5. Bar Chart to present the Preference of Colours (source: Read and Upington 2009)

2.2. The 21st Century Learning Spaces

Learning is an activity that occurs naturally in daily life in various ways. It started since we were born and keep ongoing during our lifespan. Despite it being principally an everyday activity, learning has long been associated with formal education acquired at schools, colleges, or at the higher-education. For decades, pursuing education has become a pattern in the modern society with some places even make it compulsory to some degree. With the affordability of technology devices and fast internet, nowadays people can learn and share knowledge from anywhere anytime independently. This development both offer potentials, but also pose as a challenge to the traditional educational system.

The Joint Information Systems Committee (JISC) suggests that the concept of 21st Century Learning Spaces must embrace the impact of the technology, a principle that learning facilities need to be flexible i.e. able to accommodate different learning needs; future-proofed i.e. able to accommodate new developments, bold i.e. always exploring new technologies and pedagogies, creative i.e. inspire students and teachers, supportive i.e. develop the potential of all students, and enterprising. Moreover, the learning space is expected to support and motivate learners, and that motivation can be promoted with a well-designed learning space, infused with natural light that is pleasurable to work in (2006).

2.2.1. Learning Environment

What is a good learning environment? How can it motivate the learners and improve learning achievement as JISC suggests? Although it is generally accepted that environmental condition can affect its occupants, it is still an ongoing debate the extent learning environment can affect the students, especially to their learning achievement. A story of a homeless boy ("Filipino Boy Receives Scholarship after Photograph of Him Studying on the Street Goes Viral - Telegraph" n.d.) who does his homework outside so that he could catch the light from a nearby restaurant showed two things:

a. People need a place that supports their activities adequately, but
b. Determination can overcome the limiting condition whenever required.

What is the dominant factor that influences the boy's learning achievement? Is it the physical dimension (i.e. lighting) or the social dimension (i.e. determination, homework pressure) matter most? Considering that there are many conjoined factors involved, it is debatable to determine the most influential factor. And for the boy? He received a scholarship after his photograph gone viral.

The UK Design Council has identified four elements involved in learning within schools, which are: a) Systems and Processes, b) Product and Services, c) Communication; and d) Environment, of which the latter has been more studied than other factors *(Figure 6)*, especially related to the relationship of lighting, temperature, noise and colour to education (Higgins et al. 2005). However, it seemed studies considering the learning environment in the higher-education are still lacking (Temple 1988).

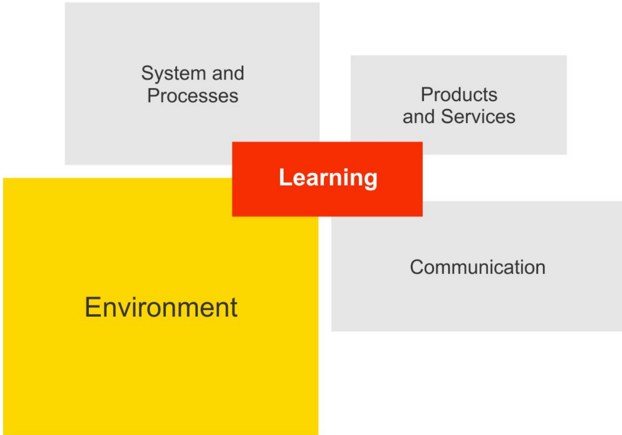


Figure 6. The proportion of studied areas
(Source: Higgins et al. 2005)

Another study considering student preferences of the learning environment in higher-education was conducted by Naibaho and Adi (2012), whereby 157 higher education students in Surabaya-Indonesia were asked to list the environmental factors that influence learning activity. The results, ranked from the top-voted are: a) The Classroom size/Spaciousness, b) Spatial arrangement, c) The cleanliness, d) Internet facilities, e) Library facilities, f) Thermal comfort, g) Noise level, h) The relationship between the students; and i) The relationship between the students and the lecturers. Therefore, based on the evaluations, the physical environment has been perceived as the most important by both experts and the learners.

The experience of perceiving the surrounding environment is very complex. When entering a physical environment as a learning space, we use all our senses to appreciate our surrounding. As Gestalt theory suggests, the process of recognition starts by looking at the whole situation, while the sensories absorb the environment. Whyte (1980) identifies three elements of an enclosed environment that influence the occupant relationship with the environment:

- Physical and ecological quality, which refer to environmental attributes. In the indoor environment, these are the air, the temperature, the lighting and the enclosure.
- Behavioural and functional, which refer to human interactions with the physical settings i.e. room dimensions, the size of the chair etc.

- Aesthetic and visual quality, which refer to subjective valuations of the place i.e. pleasing, engaging and so on. Among them, the aesthetic and visual qualities are the most difficult to measure, since aesthetic is a subjective matter, and could influence individuals differently.

As half of a human brain's capacity is dedicated to processing visual information, visual information can have a dominant effect on humans. It only takes milliseconds for a human to process visual information and make a first impression based on visual appeal. Subsequently, these data are analysed, compared to previous experiences and knowledge, and reach the behavioural level. The impact can be in a split second, but in some cases, it could take a much longer time. Norman (2004b) implies the effectiveness of the visceral design makes the first impression, in which aesthetic value can play an important role to make a great impact on perception. A successful visceral design is believed to evoke positive emotion in the users.

2.2.2. Learning Spaces Type

In the past two decades, the design of the learning spaces has evolved, especially with the addition of a variety of spaces to accommodate contemporary learning activities based on self-regulation and collaboration (Beckers, van der Voordt, and Dewulf 2016). In the UK, JISC listed four types of learning spaces based on learning activities (Jisc 2006):

a. Teaching space is the centre of learning activities, recognisable by tutor-focused arrangements, usually in a U-shaped or a straight row. Also, the presence of teaching instruments such as projectors, whiteboard etc.
b. Vocational teaching spaces i.e. a skill-specific teaching space, which has highly specific requirements for equipment.
c. Learning Centres i.e. a space for semi-formal purposed learning activities outside the teaching spaces. In this category are the library and quiet learning spaces. The library is usually recognisable by the presence of book cabinets, although it has gradually transformed itself into a digital medium.
d. Social spaces i.e. the spaces where learners, teachers/lecturers, and staff interact outside of teaching activities. Compared to teaching spaces, or a learning centre, the social spaces take different forms. It could be the corridors, the kitchens, the canteen, or the discussion room. Other spaces, like the communal study room,

resemble offices environments, which seems natural since the offices are the next place that learners go to post-education.

The *Information Commons* at the University of Sheffield *(Figure 7)* is one of the developments of social centres that also work as an information centre, library and academic community.

Figure 7. The Information Commons at the University of Sheffield (left) and Students at work at London University (right) (Source: left-author, right-Garry Knight)

2.2.3. Visual Appearance

The appearance of learning facilities has evolved along the times, which witnessing the new developments to sway away from the old institutional look, which treats the learners like in a learning factory (Leland and Kasten 2002). The Diamond in Sheffield University is one example of the recent development of learning facilities new-wave design: The interior design is a playfully-mixture of linear and curvilinear geometries washed in white colour. A contrast to the metal-cladding exterior design. The façade design also received a mixed reception, including complaints about not representing its surrounding, resulting in the building nomination for Carbuncle Award in 2016 for the ugliest building (Wainwright 2016). The over-use of informal interpretation also concerned Boys who criticised it as merely simplifying for solutions (Boys 2010), and it appears that the designer's tendency to impose their interpretation could disconnect the spaces from the users and the community, even though it is understood that the problem is not exclusively for learning facilities buildings. Rather than the designer making presumptions of the user's needs, it is suggested to involve the users in the design process to create aesthetically pleasing spaces (Scott 1993).

The appearance of the Diamond Building itself exploited geometric shapes, with a combination of linear and curvy lines in a neutral white colour, which is a contrast to the diagonally-crossed lines on the outside layer *(Figure 8).*

Figure 8. The Diamond at the University of Sheffield
(source: author)

Furthermore, learning spaces are also a beacon of diversity, used by people from many backgrounds, cultures, and languages. This characteristic is prominent in many higher-education institutions that have become a destination for international students. Despite economic and social benefits, a few issues can also occur, caused by the use of visual elements seen as inappropriate by a different culture (M. Hall 2015). To face design challenges in this situation, the designers are suggested to take a systematic approach to investigate user visual preferences. Similarly, Guerin and Mason (Ham and Guerin 2004) also suggest that interior designers need to become culturally sensitive by knowing user preferences.

In the design development process, the visual appearance is an area left for the designers to fulfil. Nagamachi, the founder of Kansei Engineering, advocates the designer should be given at least 30-40% freedom to make an aesthetically pleasing design. Given too much freedom could lead the designer to alienate the users and the environment (Nagamachi and Lokman 2010).

2.2.4. Learning Space Design Recommendations

The general recommendation for the 21st learning space design emphasises on the informal learning which addresses aspects of learning theory, placemaking, and architecture. Harrop and Turpin (2013) define Informal learning space as non-discipline specific spaces, which can be within our outside library spaces. Since a successful learning space consists of various interconnected aspects including the subjectivity of its users, most of the times it is not possible to make a bold recommendation regarding the quality required to make a successful space. Therefore, scholars usually come ups with general recommendations, for example, Tanner (2000) described that "clearly defined areas for freedom of movement" has a significant impact on students with high learning scores, as well as "overall positive impression of a school". In order to have a motivational effect, JISC (2006) suggest that a well-designed learning space filled with natural light, provide an environment that is easy and pleasant to work in.

The recommendation list in this section will specifically look at the visual environment influenced by Spaciousness, Surface Colour, and Geometric shape. The factors were selected through a preliminary study discussed in section 4.2.2 and during the development process of the platform. The list is in line with Higgins et.al (2005) who listed lighting, colours, or spatial dimensions as impactful for learning performance.

Spaciousness

The importance of the Classroom size/Spaciousness was indicated by the study Naibaho and Adi (2012). In a study involving 157 higher-education students in Surabaya-Indonesia, Naibaho and Adi distributed a questionnaire regarding the environmental factors that influence the students' learning activity, in which Spaciousness made it in the top-voted factor. Stamps (2007) infers two factors that characterized the perception of spaciousness are the floor area and the social density. He also cited Bharucha-Reid and Kiak's study of rooms with various floor area (4.7 and 22m^2) and social density (6 or 16 people). They concluded that a larger room was perceived more positively than the smaller one. In The Hidden Dimension, Hill (1988) categorized the floor area into four groups, they are Intimate distance (1 to 46 cm), Personal distance (46 to 122 cm), Social Distance (1.2 to 3.7 m) and Public distance (3.7 to 7.6m or more). A social learning space such as the Information

common has a library as one of the facilities. Neufert's (2012) suggests that a reader/student should have at least 900x60cm work table and 2.32m2 working area.
For the vertical dimensions, it is well known that people prefer high ceilings against low ceilings. Meyers Levy (2007) specifically investigated human's ability to process information in four rooms with various ceiling height. The study that involved 32 participants concluded that low ceiling height promotes focusing ability, while a high ceiling is more preferable for creative works. However, the study provided no exact measure regarding the ceiling height range.

Surfaces Colours

The recommendation can vary between writers. One says that younger children prefer bright colours and patterns (Engelbrecht 2003), while another writer suggests strong, warm colours for young children while avoiding intense primary colours (Pile, 1997). The use of intense colour, especially red induces the brain into an excited state (Küller, Mikellides, and Janssens 2009), which is not an ideal choice if the occupants need accuracy in their tasks. For that reason, some researchers stressed the importance of choosing colour based on its functional rather than from the aesthetic standpoint (Mahnke 1996b; Engelbrecht 2003). For the academic environment, Mahnke (1996a) suggests the use of cool colour for the classroom and light green for creating quietness and concentration. One piece of experimental research asked participants to perform various tasks while seated in booths which were painted in the participant's preferred colour and did suggest that learners perform better surrounded by their preferred colour (Bross & Jackson, 1981). However, since learners' colour preferences will vary widely, Woolner (2010) argues this is not a very useful result when considering what colour to paint a classroom.

Figure 9. The greyish colour scheme and cocoon-like geometric shape in Glasgow Caledonian University
Source: https://www.flickr.com/photos/jiscimages/436289622/in/album-72157626828092657/

Geometric Shape

The inclusion of window and ceiling style (a geometric shape factor) in this study occurred during the later stage of designing the platform. In the preliminary study, the absence/presence of windows was voted as the most important factor for the learning space. The Window variations were later being expanded by inducing the geometric shape factor.

Various literature suggests the design of the learning spaces today should distance itself from the traditional approach by promoting informal atmosphere into space (Jisc 2006; Woolner 2010; Harrop and Turpin 2013). Jisc specifically listed informal learning, flexible room as integral parts of an education institution offering the student the ability to manipulating the form of the room's elements. However, the author was unable to uncover a more specific recommendation regarding the learning-space design related to the geometric shape or elements' style, since there is little evidence that a specific style can influence learning activity. Also, a population may perceive informal setting differently than the others. A study that closely relates subjective preference and style of houses was conducted by Devlin and Nazar (1989). Faced with an overwhelming number of styles, they categorized the style of a house architecture into 'high' and 'popular'. 'High' is defined as designed by architects and usually featured in a professional magazine, while 'popular' is the design that is featured in a newspaper. The appearance of the 'popular' design houses is those from traditional descent, built using brick and stone, while the 'high' is more of contemporary, with a new kind of material, off-centre façade, etc. The result showed that the non-architects favoured simplicity and 'popular' attributes, while the architects favoured complexity and 'high' attributes. Although the results have nothing to do with learning space design, it is interesting to see whether there are similarities in preferences.

Figure 10 'High' (left) and 'Popular' (right) House Style
(Source: Devlin and Nazar, 1989)

One question that is difficult to answer is about how much improvement is enough considering the needs and desires of a range of school users. Research tends to reveal differences of opinions between individuals. For example, there is enormous variation in preferences for different colours so even where designers suggest that certain colours are conducive to learning or more appropriate for particular ages of children, they do not always agree with each other.

2.3. Design Participation for Learning Spaces

The concept of 21st Century learning spaces encourages the involvement of the users to improves the learning spaces. During the development of the Diamond building at Sheffield University, a few dozen students were invited in a dialogue to evaluate a range of furniture for the newly designed building. The participants then looked around to try the benches and sofas and left comments regarding the design, colour, material, and ergonomics. They then left their comments and feedback on papers to the organizer regarding any aspects the furniture they would like to report i.e. quality, design, or ergonomic. During the learning activity, the learners also encouraged to make re-arrangement of the furniture to suit their learning style. It is the *prima facie* right of all people who potentially affected by a design development to express their considerations. It is the student's right to be involved in the making of the space, which needs to be fulfilled. Brown (2007) in his book 'Communication in the Design Process' claimed to have the evidence that the majority of Lloyd building's occupants excluded in the design process found it unsatisfactory.

Design participation has many forms. Wulz (1986) identified seven levels of participation from representation to self-decision.

a. Representation is the most passive form of participation, in which the designer does most (if not all) of the design role.
b. Questionnaire i.e. using a technique consists of the statistical gathering of population's need.
c. Regionalism i.e. the combination of representatives thinking with emphasizes on the local population's preferences and value;
d. Dialogue i.e. informal conversations between the users and the designer.
e. Alternative i.e. involving the user in the design process in which the users are given choices of several alternatives.

f. Co-decision is regarded as a form of balanced participation where the population is actively involved from the early stage of a design process.
g. Self-decision is the stage where the user does most or all the design tasks with minimal or no involvement from the expert.

User involvement also can occur in different stages of a design development process *(Figure 11).* At the early stages, it is often very messy, with overwhelmed ideas, issues, and questions in the exploration of finding a design direction. Since no design proposal has been produced at this stage, there is more space for idea gathering rather than in the later stage.

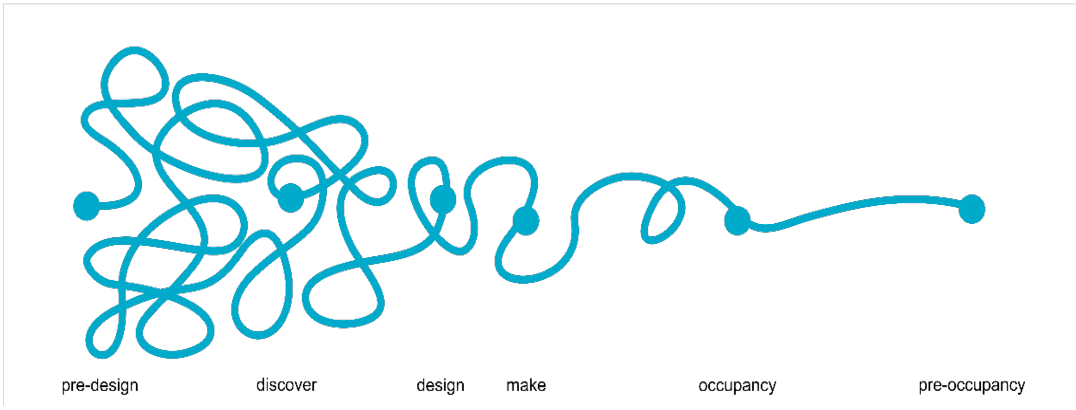


Figure 11. Design development process
(Source: Sanders and Stappers 2012)

Learning spaces users in higher-education are increasingly multi-culture that is susceptible to cultural clash in the educational society. Involving a large number of people in the early stages can bring many ideas and potential solutions, not only from the users but also from the larger community. This led the study to Co-design; large-scale participation occurs at the early stage of the design process and uses artists to help the citizen to illustrate their vision of the community. Co-design supporters insist this give them the ability to influence their built environment and helps reduce alienation in a community (King et al. 1989). However, the face-to-face public meeting for Co-design is restricted by time, place, and the number of participants. The affordability of technology devices and the fast internet not only made it possible for people to learn and share knowledge from anywhere anytime independently but also provide an opportunity for the wider community to involve in participation. The online community also offers quantity, diversity, anonymity, and independence that can be a valuable asset (Barisano 2013).

Recent developments also see the crowd potential, which sees people as creative individuals that can offer solutions to design problems (Norman 2004a). The argument is based on the fact that people have the ability to solve problems, have tastes and dreams, and can learn from the past, which makes them the expert of their own experience. Sanders and Stappers (2012, 66) categorized how the participants can involve: a) Do i.e. observing/reporting on how people do or behave, b) Say i.e. what people say in a survey or an interview, and c) Make i.e. let the participant make things/artefacts to express their mind and feel.

2.4. Three-Dimension Interactive Virtual Environment

Also known as 3D Virtual environment or virtual reality is computer-generated 3D simulation platform, often mimicking the appearance of the real world, such as the ability to interact with objects and other (networked) users within it. It has been thousands of years ago when Imhotep produced what is known as the earliest design visualization (approximately 2680 BCE) for the Stepped Pyramid at Saqqara. Since then, various visualization methods (i.e. sketches, technical drawing, model) have been used in the design process, either for idea generations or design communications with the clients. Fast-forwarding to modern times, more methods for design visualization have been developed utilizing the advancement of computing technology. And, unlike the traditional methods that are static, digital technology makes it possible to produce a dynamic presentation.

Due to its complication to create, the use of Interactive Virtual Environment (VE) in design practice is not as wide-spread as a still-3D image or 3-D animation. The 3-D animation is a sequence of rendered images, which give an impression of dynamic movement in a pre-defined scenario. The main advantage is on its capability of producing a near photo-realistic visualisation, however, the viewer has a very little control offer various aspects on the presentation. Quick-Time Virtual Reality (QTVR) offers an upgrade over the use of the image by adding a 360-degree capability to look around the environment. Depending on the image quality, QTVR is capable of creating an immersive experience, though the viewer can only do it from one standpoint. Franz (2006) demonstrated the effective use of web-based interactive simulation using QTVR (QuickTime Virtual Reality), which utilises 360-degree panoramic photos as the medium for assessing the qualities of indoor environments

(Figure 12). Emotional concepts play an important role as intermediating variables (i.e., arousal in the classic Yerkes-Dodson law, or workplace satisfaction). Thus, the study was an example of a multi-dependant study that addressing both individual attractiveness of rooms colours, and spatial properties to the presented environments.

Figure 12. QTRV for Indoor Environment Study
(source: Franz Gerald, 2006)

Interactivity in 3-D simulation grabbed people attention in the games arena by the likes of *Wolfenstein* 3-D ("Wolfenstein (Series)" 2017) and *Quake* in the '90s. While mainly developed for entertaining, the ability to explore a virtual environment also makes it appealing for design and research purpose. Current 3-D games can also replicate near real-life experiences, supported by massive budgets and years of development time. For example, *Skyrim* is rumoured to have cost 100million and took 4 years to develop. An early effort to exploit the Internet and 3-D simulation for user participation in learning spaces design had been demonstrated by Richens and Trinders in the late '90s. In the study, a third-party level editor was used to build a visualisation of a design proposal project, a new computer laboratory at Cambridge University. Although Quake II is a First-Person Shooter game, based on a very efficient game engine, it still needs a powerful computer to run *(Figure 13).* Consequently, the 3-D simulation visualisation was carried out separately in the Computer Laboratory, and used electronic mail to distribute the plan, and receive feedback from participants (Richens and Trinder 1999).

Figure 13. Quake II game engine for design visualisation
(source: Richens and Trinder, 1999)

Among the methods mentioned above, Interactive 3-D simulation has been regarded as the most difficult to use. In the desktop environment, the viewer is required to navigate using a combination of keyboard and mouse commands, which are often difficult to learn and use. Surprisingly, some studies claimed that the participants preferred the use of interactive visualisation compare to other media (Rafi, Mat Rani, and Rani 2010; Peng 2011). Peng implied that during the pre-project consultation exercise, most representative users appeared in favour of 3-D modelling as it supports intuitive understanding of spaces by a wider population of the community without the special skill of reading 2D technical drawings. UCampus is the only tool discussed here that was specifically developed for learning space design *(Figure 14).*

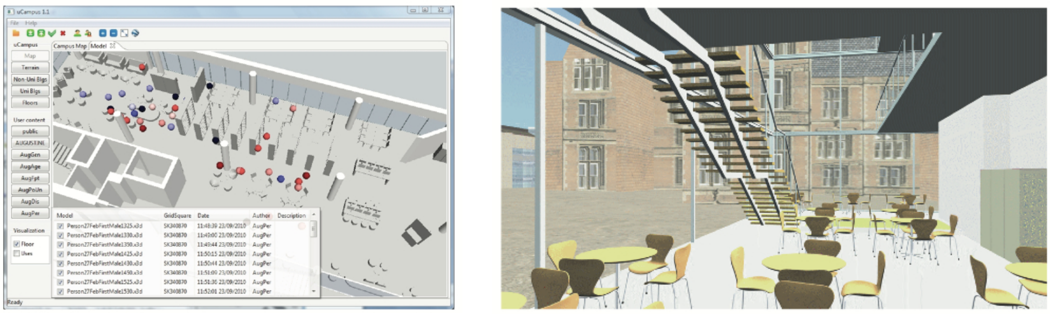


Figure 14. UCampus Interface
(source: Peng, 2011)

The tool aimed to facilitate the collaborative and coordinated design of learning spaces, by a range of university stakeholders (Basu et al. 2010). Although uCampus focused on the University of Sheffield, it can be adapted and utilised by other institutions. UCampus offers both the interior and exterior of buildings and information on how individual spaces are used, enabling different perspectives to be collected and explored in 3-D. The uCampus 3-D building models are accurate to within 5mm, which means they can be used for a variety of purposes. The users can participate to suggest new design by uploading models in real-time and decide whether their designs should be private or in the public domain. The project has been effective in achieving its intended aim of developing a 3-D visualisation and modelling application to help stakeholders in institutional building and space development better understand and visualise existing and new spaces (Peng 2011).

The following table lists some of the advantages and disadvantages of the virtual reality technology used on the experiments above. Basically, there are two of them that mostly used during the time being, the QTVR and Real-Time 3D VR.

Table 1. Three Dimension Virtual Reality Comparisons

Type	Advantages	Disadvantages
QTVR (QuickTime Virtual Reality), Panorama-based.	• High rendering quality • Relatively easy to set-up	• Limited movements to only looking around. • The VR is fixed and cannot be altered
Real-Time 3D-Interactive VR/ 3D game technology	• Free movements • Flexible, Real-Time VR can be altered • Some engines offer Web-based native support.	• Normally has a lower quality rendering than QTVR, • Requires high-performance computer for higher-quality rendering. • Requires programming language to implement, harder to learn

The experiments above were relying on the traditional VDU (Visual Display Unit) to display the visualization to the participants, either a monitor or an LCD screen. Due to its small screen size, a standard monitor is barely an ideal choice to create an impactful stimulus. The following section will focus on other methods that offer a better immersive experience to the viewer.

2.4.1. Immersive Media

Immersive media is the more advanced development that making media more immerse through technology such as Virtual Reality (VR) and Augmented Reality (AR). As reported by Dormehl, the fundamental is pioneered decades ago, even before the release of the first personal computer in 1975. The machine called Sensorama invented by filmmaker Morton Heilig in 1957 allows up to four people experiencing being in a 3D immersive world. Later in 1960, he patented a version of the idea as the world’s first-mounted display. (“8 Major Milestones in the Brief History of Virtual Reality | Digital Trends” n.d.)

The stimulus perceived from the Immersive media is engaging and can be very powerful, thus has been used to treat specific phobias since the 1990s. Although Immersive technology has been around for some time, they are not for general consumers. A realtime 3D Virtual Reality is an expensive piece of technology, difficult to set-up, and power-hungry in a way that it needs a powerful set of hardware to run smoothly, especially the *CAVE (Cave Automatic Virtual Environment).*

Figure 15. Head-Display Mount device (left) and CAVE (right)
(Source: https: www.independent.co.uk and www.technobyte.org)

In 2012, Oculus VR has successfully been crowdfunded to develop a prototype Head Display Mount (HDM) device for commercial use, which also initiated various companies releasing their version of the device. Having tried the HDM device, the author felt uncomfortable after some time of using it.

Considering the advantage of Immersive technology, an increasing number of studies decided to incorporate the technology on various disciplines. Lindsey (1998) and Drettakis (2006) have explored the potential use of the Immersive media for the Interior space and the urban landscape. In the study, Lindsey compared simulation and the real world using Headgear unit. Despite all the participants agreed that the equipment and its resolution were distracting, they also agreed that the VR simulation can depict the real environment. Patera and Draper (2015) conducted a study investigating the effect of colour in a room. Reasoning their choice of using VR, they argue that despite the technology might not yet produce a very realistic environment, it could offer the participant the feeling of being inside real interior space from an egocentric point of view. The two-stages experiment involved 20 students investigating the perceived wall colour effect in various size settings, in which the VR session was done in a Digital Design Studio. The aim is to let the participants experiencing the room's colour they have chosen on the first stage, and then re-evaluate their experience in a group discussion. Although immersive media was used, the interactivities were limited just for navigation, and the researcher's involvement was required to change the virtual environment colour's setting prior to the second stage.

The 3D Interactive Virtual Environment is not the easiest visualization method, though it still gives the best experience to the viewers in many aspects, especially when Immersive technology is applied. However, the traditional VDU also has its biggest potential, which is the availability among wider users. In some studies where the participants are the crowds from different places around the world, this is a crucial aspect.

2.4.2. Validity and Usability Issues

The use of simulation still receiving a lukewarm reception by environmental psychologists, due to the notion that real environments are too complex and cannot be simplified in laboratories (Pol 2006). While quasi-photorealistic visual quality could be important for transferability (Daniel & Meitner, 2001), many studies have demonstrated that the current standard is able to deliver experiential qualities similar to reality. Decades ago, Lindsey and McLain-Kark (1998) carried out a study to investigate whether the observation of a virtual environment provides the same characteristics of the existing interior environment. Using Immersive virtual reality (VR) on a head-mounted display (HMD), the researcher observed twenty-four volunteers completing various tasks in the virtual and real environment. Subjective evaluation was done using questionnaire read to the participants. The results concluded that VR can be a viable method for various planning and design tasks.

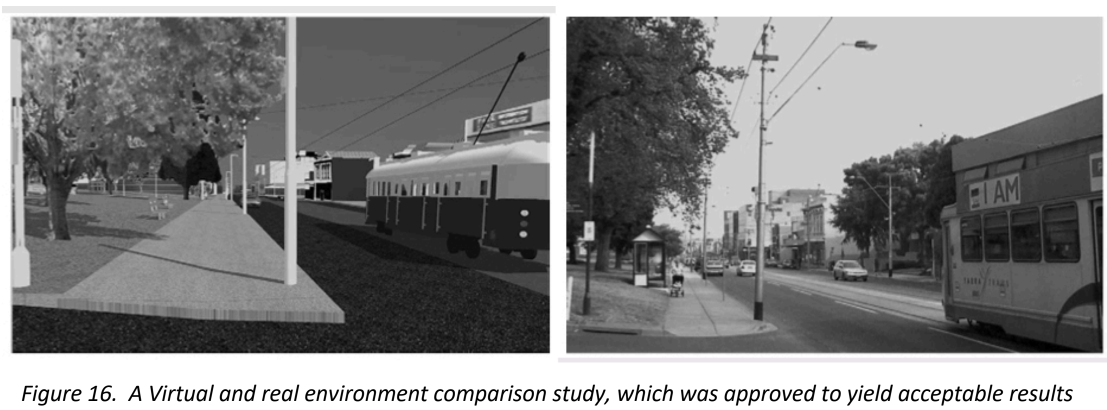


Figure 16. A Virtual and real environment comparison study, which was approved to yield acceptable results (Source: Bishop and Rohmann, 2002).

Bishop and Rohrmann (2002) conducted a similar study to investigate the subjective response to the simulated and real environment of urban parks, which also proved the ability of computer simulations to yield acceptable results. However, they cannot generate the same response as in the real environment *(Figure 16).* Drettakis et al. (2006) take the realism even further by featuring 3D sound, high-detail plantations, and shadows in a virtual environment study using virtual reality. Nevertheless, a simulation will never be perfect in every aspect of the real thing it tries to simulate. There is always the advantages that make the simulation as an ideal choice, for example is the ability to control undesired environmental factors. While Drettakis implies that the absence of sound is a great lost for virtual environment, Rafi and Rani (2010) argue out that the absence of the weather factor allows the participants to focus on the visual aspect of the simulation. Im (1984) also infers that in the absence of other factors, visual preferences become important.

2.4.3. Usability Test

With various new tools and methods being created, no ultimate measuring tool can be used to evaluate all different requirements. In the consumer industry, at least three indicators are generally used by the developers to evaluate their work, product, or creation: a) the expert's acceptance, b) the user's acceptance, and c) the market result. If an established body existed to make an independent evaluation, they could conduct a rigorous test for the product for reliability, validity, or usability. In many occasions, the developer must do the test themselves. In the movie industry, sometimes the producers do a movie-screening to see the reaction of the audiences. It is not uncommon the movie-makers need to alter the movie based on the audiences' reactions.

For developers of hardware and software, before releasing a product, the creators need to predict how their creation will perform, and if possible, market acceptance. The typical method is to develop a pre-release version and test it among the users in the normal use scenario. The test is held either in a controlled environment or at home, with a different time limit. The feedback gathered from the users can identify the problems of the pre-release version, although it is still not easy to measure since the product and the users' characteristic is not unidimensional. Gabbard, Hix and Swan (1999) proposed a user-centred design and evaluation approach for virtual environments, which consist of the following steps:

- User task analysis i.e. observe and identify the tasks required for the system,
- Expert guidelines-based evaluation i.e. involving the experts to identify the problems of the proposed system.
- Formative user-centred evaluation i.e. involving the users to carry out task scenarios.
- Summative comparative evaluation.

Concerning a usable product either hardware or software, there are two types of the usability test: a) Subjective evaluation to evaluate the participant opinions regarding the product's usability, while b) Objective evaluation to evaluate the participant's performance during the scenario. After-Scenario Questionnaire (ASQ) is one of a few other usability tests at IBM (J. R. Lewis 1995), which deal with the use of a product such as software development. The others are PPSUQ (Post-Study System Usability Questionnaire), QUIS (Questionnaire for User Interface Satisfaction), CUSI (Computer User Satisfaction Inventory). However, they are not specifically designed for use after using the instrument. The ASQ consists of three constituents:

1. Easy of task completion
2. Time to complete
3. Adequacy of support information (assistance, documentation)

The fact that the questionnaire is short makes it appealing for the participants to complete, rather than a lengthy questionnaire. The drawback is its simple approach is not designed to identify every problem, nor every potential of the platform. Therefore, this research expanded the evaluation to investigate a few specific functionalities not addressed in the ASQ.

Projects and Usability-Test

In 2006, Drettakis et al. (2006) designed and evaluated a Virtual Environment (VE) platform for architecture and urban planning. It allows the user to manipulate the elements in the Scene (i.e. benches, umbrellas). The user can navigate through different views, i.e. Top, perspective, balcony. A preliminary survey was conducted involving end-users (architects, chief engineers, and decision-makers), followed by deciding the elements required to make the platform useful. The VE employed a high level of realism provided by Virtual Reality (VR) technology *(Figure 17).*

Figure 17. Interactive 3-D Virtual Environment for Urban Landscape (source: Drettakis et al., 2006)

To evaluate the platform, the researchers involved 3 participants indirect observation and videotaped them. During the experiment, the participants undertook the following activities: a) User performed various tasks, b) Post-experiment questionnaire, and c) Post-experiment interview. The questionnaire was developed on a 1 to 7 Likert scale to evaluate the effect of realism and user's perception on the effectiveness and efficiency of the platform. The usability test results showed that in term of ease to use the platform scored 4.7 (1 to 7) with 2.5 standard deviations and for the effectiveness and efficiency 5.0 SD=1.7. Another study is a web-based platform created by Vosinakis et al. (2007), which was designed to support the design and evaluation of interior spaces, employing 3-D virtual environment technology. The application created by Vosinakis and others, aimed for use at the early stage of a design process, allows the user to construct an idiosyncratic room and to arrange the furniture using the provided tools.

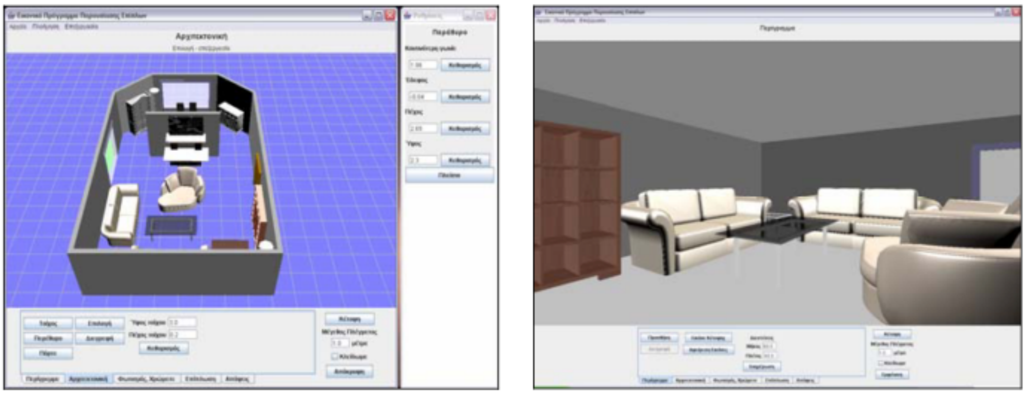


Figure 18. Web-based platform to support the design and evaluation of interior spaces (Source: Vosinakis et.al, 2007)

A usability test was conducted on a 1 – 7 Likert scale, involving 11 computer-literate participants aged between 28 to 45. None of them had experience in using 3-D and CAD applications. In the test session, the participants were required to complete a specific scenario involving: a) modelling of a room, b) adding the doors and windows, c) place the furniture, d) lighting, and e) navigation. Overall, the task completion time was between 8.34 to 19.28 minutes. Upon completion, the users filled-in a questionnaire concerning its usability for each of the main function. The result showed the mean rating for architecture design: 5.09, furniture selection and arrangement: 5.0, light and material: 5.27, and navigation 6.09.

Chapter 03
Research Methodology

To answer the research question, this chapter will discuss the philosophical approach, strategy and the design in this study, and how the data will be collected, analyzed.

3.1. Research Philosophy and Approach

Research philosophy is a principle concerning how the data should be collected, analysed and used. The term epistemology (what known to be true) is the opposite of doxology (what believed to be true). Science aims to change a belief into a knowledge: Doxa to episteme. Two research philosophy has been recognized in western practice, they are positivism and interpretivism (antipositivism). (Galliers, 1991)

Positivists consider that reality is stable and can be observed and defined from an objective viewpoint. They contend that occurrence needs to be isolated and repeatable. This principle often requires the manipulation of reality with only one independent variable, in order to identify regularities and to build between the elements of the social world. Despite positivism has a successful association with physical sciences, there has been a debate whether or not it is suitable for social science (Klein and Hirschheim 1985). The main reason is the failure to appreciate the role of the observer's social context (i.e. historical, social conditions) which influence the social beliefs.

On the other hand, the supporters of Interpretism argue that reality can only be fully understood through subjective interpretation and intervention of reality. Phenomenon studies in their natural environment are the key to the philosophy, along with the acknowledge that science also influencing the phenomena they study. They admit that interpretations about reality could vary but insist that they are part of the knowledge. Both research approaches have a long history since the era of Plato and Aristotle (positivists), and Sophists (anti-positivist). Since that time, positivist tradition has dominated most of the research in the US (Orlikowski and Baroudi 1991). However, it has been acknowledged that no research methodology is fundamentally better than others.

This study involves an element of technology that never been used previously, therefore requires an effort in the implementation process. In a user-centric process during the design and development, the interpretivism approach may occur during the participant's involvement, especially while analysing and interpreting their requirements. In order to investigate the feasibility and to analyse the result would be impossible without positivism being involved since Interpretivism research sometimes associated with a lack of objectivity. Therefore, this study mainly adopts a positivist, quantitative approaches to the development of the proposed method and tool, marked in (greyed shade) bellow.

Table 2 Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (Creswell, 2013)

Tend to or Typically	**Qualitative Approaches**	**Quantitative Approaches**	**Mixed Methods Approaches**
Use these philosophical assumptions *Employ these strategies of inquiry*	Constructivist/ transformative knowledge claims Phenomenology, grounded theory, ethnography, case study, and narrative	Post-positivist knowledge claims Surveys and experiments	Pragmatic knowledge claims Sequential, concurrent, and transformative
Employ these methods	Open-ended questions, emerging approaches, text or image data	Closed-ended questions, predetermined approaches, numeric data	Both open- and closed-ended questions, both emerging and predetermined approaches, and both quantitative and qualitative data and analysis

The research approach set a plan and procedure consisting of the steps of broad assumptions to detailed method of data collection, analysis and interpretation. It is, therefore, based on the nature of the research problem being addressed. The research approach is basically separated into two categories:

- the approach of data collection and
- the approach of data analysis or reasoning.

3.2. Research Strategy

Galliers (1987) listed fourteen research methodologies, as reported by Africanus and Davidson (1991) separated in their paradigm as Positivist or Interpretivist (Table 3). This study adopted surveys and simulation, marked in (greyed shade) on the table, which will be further discussed in this section.

Table 3. Research Methodologies Lists (Galliers, 1997)

Scientific/Positivism	**Interpretivism/Anti-positivism**
Laboratory Experiments	Subjective/Argumentative
Field Experiments	Review
Surveys	Action Research
Case Studies	Case Studies
Theorem Proof	Descriptive/Interpretive
Forecasting	Future Research
Simulation	Role/Game Playing

- Laboratory experiments allow the identification of relationships between a limited number of variables inside a laboratory environment. Quantitative analytics is used to help to make general statements that are applicable to the real situation. The critic of the laboratory experiments pointed out the oversimplification of the situation, which is unlikely found in the real world. Field experiments expand the laboratory experiments into real-life situations in order to reach a higher level of realism.
- Surveys enable the collection of data through questionnaires or interviews from the participants at a time regarding practices, phenomenon, or thoughts. Depending on the type of the survey, either Quantitative or qualitative can be used to analyse the data to find relationships.
- Case studies are an effort to link the relationships that happen in the real world. It can be either positivism or interpretivism, depending on the approach, the data collected, and the analytical technique employed. Case studies weakness is that it often limited to an organization and it is difficult to generalize the finding since it is hard to find similar cases. Furthermore, every researcher may have their own subjectivity over the same data.
- Forecasting research involves techniques such as regression and time series analysis to make guesses of future events. This is very useful research to deal with the fast changes

in IT and to predict its impact on individuals, organizations, or society. However, the result can be uncertain as the relationship with real-world events is difficult to predict.

- Simulation involves imitation of the behaviour of a system. It is normally used in situations where it would be hard or impossible to conduct the event in real-life (i.e. dangerous), often to predict the future or gain a better understanding.
- Subjective argumentative requires the researcher to implement a creative or speculative standpoint rather than act as an observer.
- Action research is a type of applied experiment in which the researcher develops a solution that has practical value among the subjects involved in the research, and at the same time seeks to build theoretical knowledge. By directly intervene in the problems, the researcher aims to reminded existing theory in the field. Similar to the case study, it is difficult to generalise the findings in action research as each case has its own interpretation.

There are two main reasons this study adopts survey research: Firstly,
Preference study collects data through questionnaires or interviews from the participants as the subject of an experiment or observation to investigate their tendency over a stimulus. Secondly, this study also involves the participants during the designing and developing of the proposed method and tools. Few drawbacks that usually found on this research method are:

- Lack of Depth. Most instruments for a survey, like a questionnaire, is standardized aiming for the general population, thus it can be difficult to ask a more specific question to the participants.
- Inflexibility, which means the survey depends on the instrument's reliability in collecting data. The researcher will not be able to alter the question during the survey, or asking in-depth questions.

As previously mentioned above, this study involves an element of technology that has not been implemented before. The main part of this technology is the use of simulation, which will be the instrument for the survey. Although the author maintains a firm belief that the best way to conduct a preference study is through experiencing it in a real situation, this is not always the best solution in many cases. Therefore, the survey adopts the simulation using the 3-D Interactive simulation as the presentation layer, except for the usability test and feedbacks. The feasibility evaluates the technical aspect i.e. how to make it work, while the users evaluate its perceived usability using the IBM's After Scenario Questionnaire (ASQ).

Descriptive research to investigate the feasibility of a method and a tool for expressing visual preferences for learning space, and then to assess the visual preferences results through the proposed method. Bhat (n.d.) defines the descriptive research as a research method that describes the characteristic of the population or phenomenon being studied. One of the characteristics is the quantitative research method to collect quantifiable information for statistical analysis of the population sample, which is appropriate for visual preferences survey as this study.

Therefore, the study will conduct an experiment involving participants and then report the results. In general, this study is grouped as follow:

- Design and Implementation. Based on the literature, previous attempts, and preliminary study, the design then implemented into a prototype using available technology, carry out a pilot test, and make revisions whenever required.
- Two-Stage experiment. Online Survey/questionnaires using the proposed instrument to make it accessible on a large-scale for participants from different locations to express visual preferences. The survey is predominantly visual, using the 3-D Interactive simulation as the presentation layer, except for the usability test and feedbacks. The visual preference results from the survey were then processed, analysed and presented to the designers. Another online survey was then conducted to record the responses. Along with the online survey/questionnaire, the study also makes an observation on the designers' responses in a two-stage experiment, before and after being informed of the previous result.

The following figure describes each step carried out in this study (Figure 19).

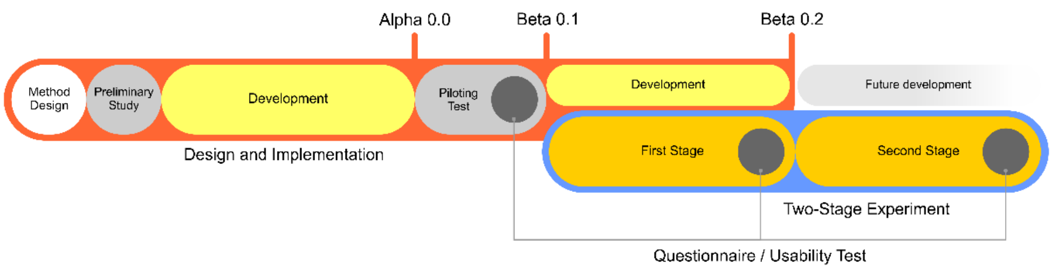


Figure 19. The steps diagram for the research

3.2.1. Design and Implementation

Method Design

At this stage, the study reflected on the previous methods and tools for user involvement related to indoor environments and the enclosed urban environment, during which the advantages and the weaknesses were investigated. This was based on the information from literature on previous methods, the available technology and tools, and a system design then proposed as guidance to develop the application. Several studies infer the use of 3-D interactive simulation as the preferred method selected by the design and non-design participants for the appraisal survey (Rafi, Mat Rani, and Rani 2010; Peng 2011). Therefore, a 3-D Interactive simulation was considered as the presentation layer to collect data from the participants.

Preliminary Scoping Study

Part of the preliminary Study is basically an interaction with the users and ask questions regarding their perceived importance of a few visual elements for learning spaces. The result of the preliminary study will give an idea on

Based on the system design, the preliminary study investigated the method to develop the application. There were two main objectives in the preliminary study:

- To review and find the available tools to develop the application. The tool can be computer applications or web-tools that can be used independently, or with each other, to deal with the front-end and the back-end.
- To conduct a survey involving students in higher education to decide the visual variables that should be considered for implementation. The result is a priority list

of visual variables for the learning space, which was useful to split the development process due to time limitations for the study.

Implementation

Based on the system design and the preliminary study results, the implementation process proceeded to the development stage. Using the development tools, a 3-D model was then built for the virtual learning spaces, and interactivity was added to allow the participants to express visual preferences. Principally, the instrument features as the presentation layer to gather data, and as the usability test medium, that consists of a three-component questionnaire regarding the participants' satisfaction with the system's usability. The test was integrated after the completion of the tasks.

The development process needed to investigate a suitable solution for the following aspects:

- The visual appearance of the simulation.
- The navigation for the agent to explore the space.
- The interface to enable the participants to alter the visual variables through the parameters.
- The workflow of the application from the introduction to completion.
- The questionnaire contents and interface.

The back-end needs to investigate the solutions for the following aspects:

- The signup and login system.
- The parametric aspects to modify visual appearances.
- Data management within the application.
- The connection to the cloud database
- The analytics process and data visualisation

The first version of the application was the Alpha version, which was ready for testing involving participants.

The Piloting Test

The Piloting test prepared p-VE for the main experiment by testing its feasibility, and the usability with a limited number of participants. In many aspects, the Piloting test is the embryo of the main experiment, which in this stage was also being reviewed. As an online survey, all the processes from inviting the participants to the data collection were carried out through the Internet.

The results and feedback from the participants were then used to develop the p-VE further for the main experiment with a much larger sample of participants. The updated version is coded Beta 0.1. Another version of p-VE (coded as Beta 0.2) was also prepared for the second stage, aimed at professional designers.

3.2.2. Two-Stage Experiment

As previously mentioned, the experiments in this study also function as scenarios to test the application. Therefore, versions of the application in the experiment also consisted of a usability test questionnaire.

The First Stage

The purpose of the first stage was to collect expressed visual preferences from the participants, as well as further testing to the application (Beta 0.1). The procedure mirrored the Piloting test, in which the participants were invited through the Internet to express visual preferences on learning spaces, and subsequently respond in the After-Scenario Questionnaire upon completion.

The Second Stage

Initially, the study was due to be carried out in one stage only. The addition of the second stage was decided upon reviewing the results of the Piloting test, which will be explained in different chapters concerning the Piloting test results. The second stage specifically invited professional designers to investigate their responses to the results of the first stage. Prior to the Second Stage, the designers were required to do the first stage before being informed of the results by all other participants.

Data Sampling

Sampling refers to the selection of people who will serve as a representative of the population of interest. There are a number of approaches to sampling:

- Opportunistic Sampling i.e. involving people who are easiest to get.
- Representative Sampling i.e. involving people who reflect the composition of the population.
- Purposive Sampling i.e. involving most of the variation in the group, and also few samples outside of the population. Usually used when conduction survey at the beginning of the design process, when differing opinions are valuable.

This study involves participants on four occasions. Since the centre of this research is on the generation of relevant ideas for the learning spaces design, it is essential that a diverse group of people be selected. Hence, Purposive sampling was used for most of the experiment, except on the Second stage that involved only professional designers.

Chapter 04
Design and Implementation

4.1. Method Design

In a learning space, the learner has the ability to customize the furniture as they please i.e. re-arrange the tables or the lighting condition to support learning. However, other elements are mostly permanent i.e. the spatial dimensions, the windows, the surfaces' colour, etc. Involving the learners in the early stages of the design process offers an opportunity for the users to inform the designers of their preferences beforehand. Since no design proposal has been produced in the early stages, this method can work as a brief that is not bound to the restrictions posed by the building's site and enclosure. The learners have the right to speak out regarding the visual quality they expect to present, and the best way to discuss the visual quality is by speaking the language of visuals, which the proposed method tries to facilitate. The core of the proposed method is the Interactive 3-D Virtual Environment, which then is applied to a platform for large-scale participation.

4.1.1. Parametric Virtual Environment (p-VE)

Parametric is a mathematic term to refer to the usage of parameters or variables that can be altered or manipulated to generate a specific outcome (Frazer 2016). Parametric design as a design tool has been made popular by various commercial Computer-Aided Design (CAD) applications, such as ArchiCAD and Revit. The tool enables the creation or manipulation of a multi-element object i.e. a table, a chair, house etc. without losing the basic characteristics of the elements. In a conventional object manipulation, each element related to the object needs to be manually adjusted to compensate the object's changes, which are mostly time-consuming tasks.

The capability makes it easier to create and manipulate 3-D objects and has impacted the growth of consumer-based 3-D design applications for mobile devices.
The programming skill is usually required to access parametric design potential, and generally difficult to learn. For example, Autodesk introduced LISP scripting language to improve productivity in AutoCAD. Thus, the use of parametric design is not common among designers who are a non-programmer. In a recent development, few developers have released a programming tool capable of generating and manipulating 3-D objects using visual scripting.

Using parametric modelling in the desktop environment, the proposed method expects to enable participants to express visual preferences by constructing a scene of the preferred learning space. A set of parametrically-modifiable visual elements is provided in the system. The creation process itself requires meticulous activity in choosing and composing the elements that make up the ideal scene. During play, the system captures the collection of selected values and sends them as scene data/artefacts to a database. On the other end, the data can be accessed as a scene, or a visual analytic form, by anyone who holds access authority, either the designers, participants, or decision-makers. *Figure 20* below shows the diagrammatic System design of p-VE.

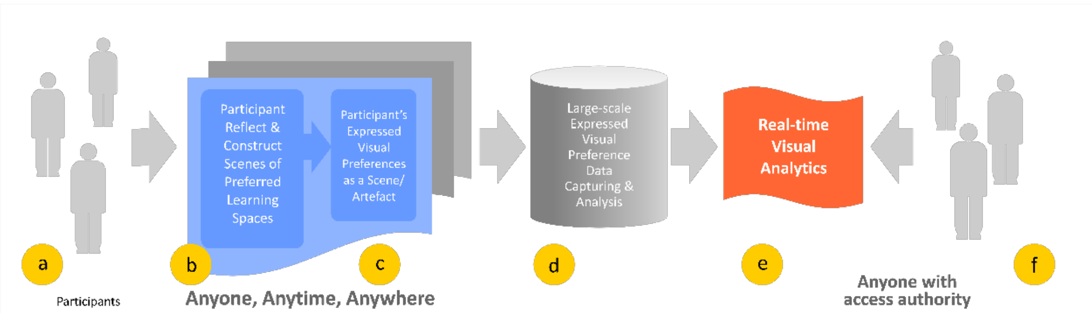


Figure 20. The system design of Parametric-Virtual Environment (p-VE)
(source: author)

a. Participants are invited to express visual preferences regarding the visual quality of learning spaces through the application. The participants can be the users (students, staff), or anyone who is concerned about the learning spaces.
b. Since the participants have been aware of the task, they reflect the past experiences and constructed scenes of Learning Spaces.

c. The proposed instrument provides the tools, which enabled the participants to express their visual preferences and create a scene of the learning space.
d. The data was then sent to an online database, which stored the scene along with other's creations.
e. A real-time process collects the data from the database, analyses it, and presents the visual analytics.
f. Anyone who has the authority can access the data collected, either as an artefact or visual analytics. For a designer, the results can assist them to develop design proposals feedback or make design decisions.

4.1.2. Large-Scale P-VE

The Front-end is the presentation layer, as seen by the users (3-D simulation, buttons /sliders, menu, etc.), while the Back-end deals with the interactivity, data management, connection to the cloud database, and visual analytics. To make it accessible to anyone, anytime, anywhere, the Front-end was made available online and can be accessed through the Internet *(Figure 21). SketchUp* was used to develop the 3-D models, while *Playmaker* added all the interactivities within Unity 3-D. Most of the movements used in this platform are basic manoeuvres such as move and scale. The platform stored the collected data in *Parse* which supports Playmaker and Unity 3D.

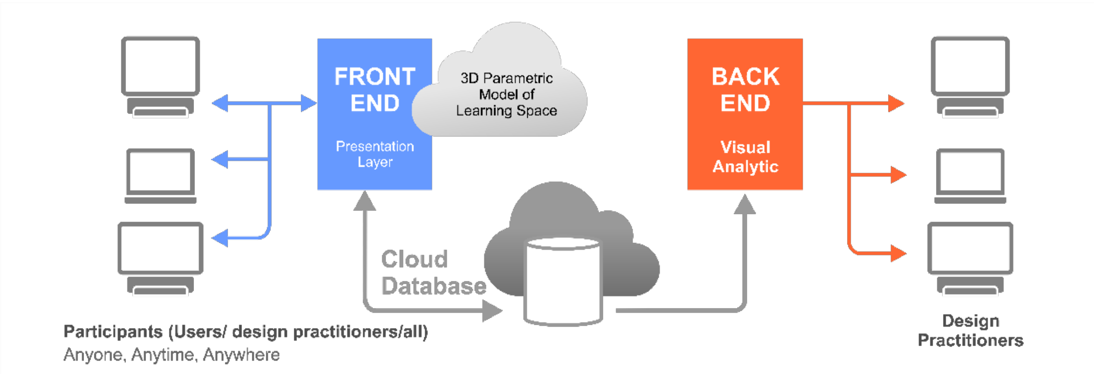


Figure 21. The Implementation of p-VE into a Large-scale p-VE
(source: author)

The Design of the application consists of several elements:

1. The Front-end is the presentation layer as seen by the users i.e. 3-D simulation, demographic survey, interface, supporting, etc. The 3-D simulation is the core of the application where the experiment takes place and be accessed by anyone,

anytime, anywhere. Since this study also tests the proposed method and instrument, it also includes a usability test.

2. The Back-end deals with the instructions to control the interactivity, data management, connection to the cloud database, and visual analytics.

4.2. Preliminary Scoping Study

4.2.1. Review of Existing Development Tools

The next step is to find the tools to implement the method. These are computer applications or online tools, that can be used to build the online 3-D interactive simulation, and to connect it to an online database. There are probably other alternatives that can do a better job in this area. However, putting budget criteria into consideration, the study mostly used open sources, freeware, and trialware applications. Having no previous experience in programming 3-D interactive simulation, the author also requires tools that do not have a steep learning curve. Since there is little documentation available, the online communities had a major role in assisting the development of the p-VE.

Parametric Design Tools

Processing was the first application tried for the implementation. It operates on Java-based scripting, which is hard for beginners. On the other hand, it has many potential, is flexible, and most importantly can generate online applications. *Processing* is also popular among architects for experimenting in *Parametric design* projects, with plenty of extensions by a third-party that can extend its functionality. *Processing* had previously been the leading candidate to implement the method, which had seen the development of a few early parametric models for this study. The first was a simple room with modifiable wall colour. The second one was a simplistic classroom that had modifiable wall colour and spatial dimensions. It also features a camera that can look around from one viewpoint. Even there was an early involvement with two students using the parametric model. Processing typically uses sliders for the interface to allow the agent to make modifications (i.e. change colour), which is relatively accessible to most users. However, the author struggled to find a solution to connect the application to an online database. In conclusion, despite *Processing* posing a decent solution to building online 3-D interactive simulations, it requires extensive scripting tasks for the purpose of this study. Moreover, despite it being possible to connect *Processing* applications to a database, a feasible solution could not be resolved.

Grasshopper is an extension for Rhino 3-D that is also popular for developing parametric design applications *(Figure 22). Grasshopper's* high point is the use of visual scripting that is easier to learn in comparison to the text-based scripting used by many others. The generative capability is provided by its host application (Rhino 3-D) that makes them powerful for developing a 3-D interactive simulation that requires the application to generate 3-D models, which also make them a perfect pair for parametric designs. However, the author could not resolve a solution to implement them as an online application, as well as to connect it to an online database. This is understandable since its host is a power-consuming application that poses an obstacle for online implementation.

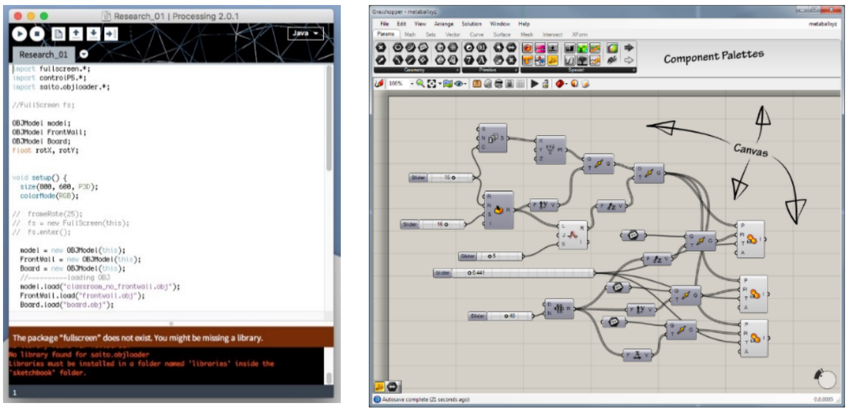


Figure 22. Processing (left) and Grasshopper interface (right)
(source: author)

Game Development Tools

Unity 3-D emerged as the leading candidate to develop the instrument. It is a cross-platform game engine that can generate applications that operate on various operating systems, devices, and on web-browsers, hence its popularity among game developers. One major drawback of Unity 3-D is its dependence on third-party applications to generate complex 3-D objects. It cannot generate its own geometry, nor control the behaviour of it. Therefore, the implementation needs to adjust to Unity 3-D capabilities by simplifying a few initial requirements that are too complex. Natively, to add interactivity to an object in Unity will require the programmer to use either C Sharp, JavaScript or Boo scripting languages. Each has its weaknesses and advantages. While C Sharp is popular for multi-platform gaming, most Unity 3-D tutorials are using JavaScript. To make an object parametric modifiable, the script that contains the algorithm needs to be attached to it. *Unity 3-D* also includes some ready-made assets that proved usable for 3-D interactive implementation, especially Character Controller, that are found inside Assets-Import Package-Character Controller. This asset creates a first-person camera view embedded to an object that is equipped with a few basic movements i.e. forward, backwards, left, right, and jump. Once the asset has been imported, it is placed in Projects inside the Assets folder. To apply the Character Controllers, first find it in the Standard Assets folder and drag it into the scene. The camera tilting and rotating are doable using mouse movements. This set of navigation gestures has been widely used in various 3-D computer games since the late eighties, thus it is familiar to many gamers. In the implementation, the asset required a few modifications to make it work with the system design.

During the development stage, efforts have been made to involve a programmer to implement the proposed method using *Unity 3-D*. A programmer had worked for a few months and made a few iterations but dropped off due to work commitments with other projects. Despite having no previous experience in programming, the author initiated the development of the instrument. Having no previous experience in programming, and self-preferences to work with visual scripting, an extension of *Unity 3-D* emerged as a solution.

Visual Scripting Tools

Playmaker is a visual scripting extension that works in Unity 3-D *(Figure 23).* Principally, it works similarly to Grasshopper by visually connecting a set of actions onto an object that will behave accordingly i.e. to change size or colour. The visual scripting makes it easier for beginners to access the functionality in Unity 3-D without the need to learn programming languages, while still allowing the addition of script whenever necessary. Although publications for Playmaker are non-existent, there are countless tutorials to learn by from the online community.

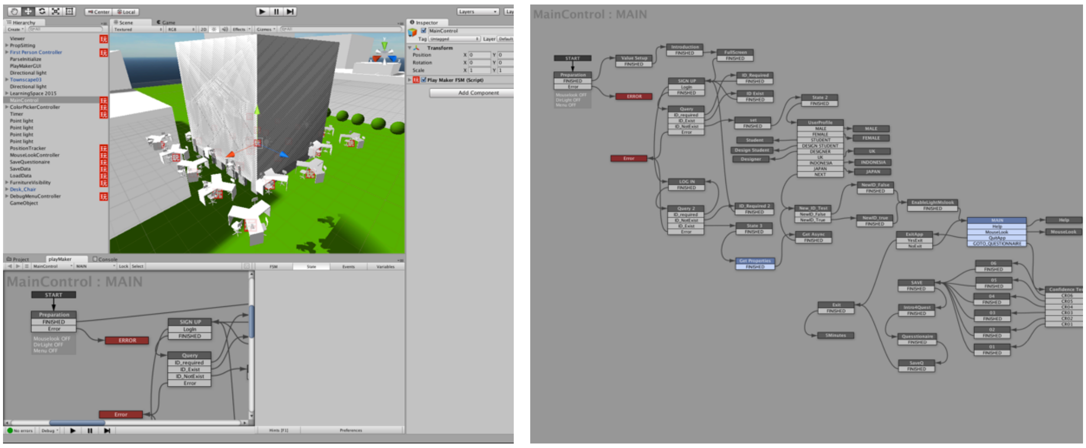


Figure 23. Unity 3-D (left) and Playmaker Interface (right)
(source: author)

Since both tools are popular among online game developers, many cloud database providers release their integration tools to work with *Unity 3-D.*

Cloud-backend Database

Parse is a cloud-backend database provider that had a good collaboration with *Unity 3-D* for data exchange from the online applications built with *Unity 3-D* to its cloud database *(Figure 24). Playmaker* and *Parse* also work together to make the integration relatively effortless, compared to other methods such as SQL. The result is still far from perfect and it lacks proper documentation. Nevertheless, it offers a feasible way for a non-expert to connect an online application to the cloud database. To use the service, the developer needs to register to the *Parse* website and download the files required onto the software used to develop the instrument. The data generated by the online application will be sent to *Parse* and can be accessed through the *Parse* website. The dashboard on their website also does a few basic analytic functions. For manual analysis, the data can be downloaded into a JSON format and converted into a spreadsheet. As previously mentioned, during the development of the instrument, there was little documentation regarding the use of *Parse* with *Playmaker*. Most of the available tutorials are aimed at text-based scripting.

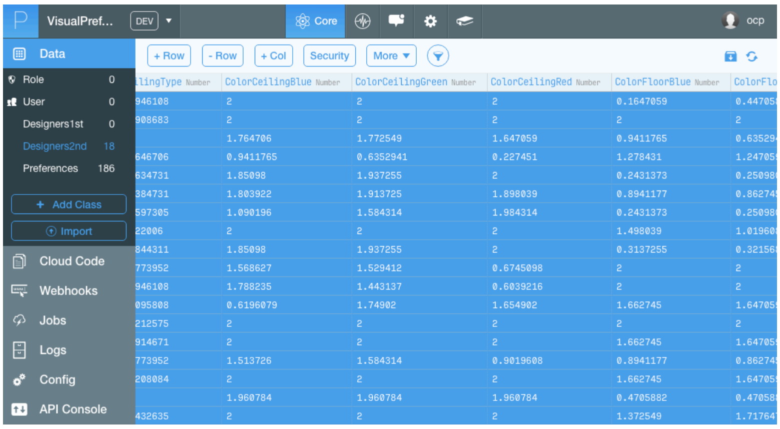


Figure 24. Parse Dashboard
(source: author)

Three-dimension Modelling Tools

SketchUp was used for preparing the 3-D models on most occasions in this study *(Figure 25).* The Pro version is capable of exporting FBX that are required by the *Unity 3-D* environment. It was chosen due to the author's familiarity using it and had access to the Pro version. *Blender* is also a decent alternative. It is an open-source application that is free to use and has been reported to work well with *Unity 3-D*. Other popular applications, such as AutoCAD, 3-D Max and Maya also offer the feature. To connect it with *Unity 3-D* is seamless. Once the FBX file was exported, it only takes a drag and drops to move it into the *Unity 3-D* environment. One issue that appears during conversion is the *Unity 3-D* unit system. Regardless of the dimensions of the object, the longest dimension of the object will be recognised as one unit in *Unity 3-D*. The issue will not pose many problems if the object's scale is fixed in size. However, when the object is size modifiable, extra effort is required to convert the unit into the intended size.

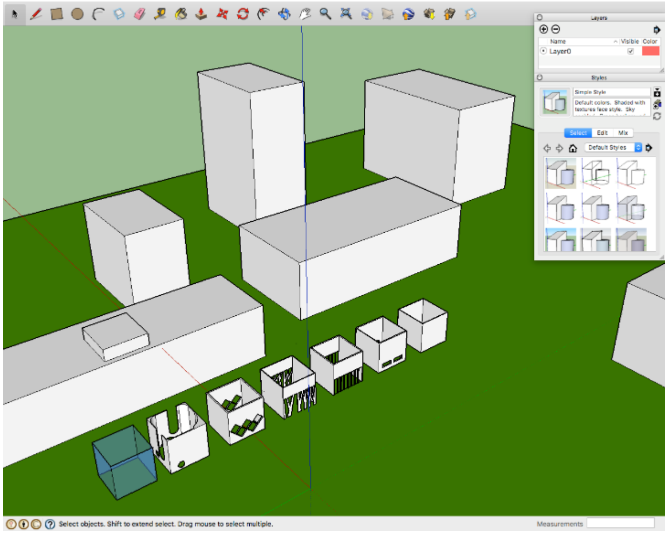


Figure 25. SketchUp Interface
(source: author)

4.2.2. Preliminary Survey

An online survey was carried out among higher-education students to rank the visual variables for the learning space design. As previously mentioned, the result is a priority list of visual variables that should be considered for implementation.

Procedure

A list of eleven possible visual variables of indoor environments was prepared. Most of them were derived from Scott's study (Scott 1993). Each variable was accompanied with a pair of images illustrating two opposite *collative property* conditions i.e. simple-complex and absence-presence. The images were created in a non-photorealistic greyscale 3-D computer generation, except for colour related variables that were presented in colour. The students then rated each variable on its importance for learning spaces, using a five-point Likert scale, ranging from unimportant (score: 1), less important (score: 2), undecided (score: 3), important (score: 4), or very important (Score: 5). The complete questionnaire can be found in Appendix C.1.

Among the twenty-four students that participated, twenty-three responses were valid for the analysis. Based on the location, 5 are from Europe, 11 from Asia, and 1 each from Australia, the Middle East, North America. Five others did not mention their location.

Data Analysis

The data then processed in SPSS for reliability analysis, in which the reliability coefficient (Cronbach's alpha) for the questionnaire set was determined to be 0.756 based on eleven items. Descriptive statistic then used to generate the mean score of each variable and rank them.

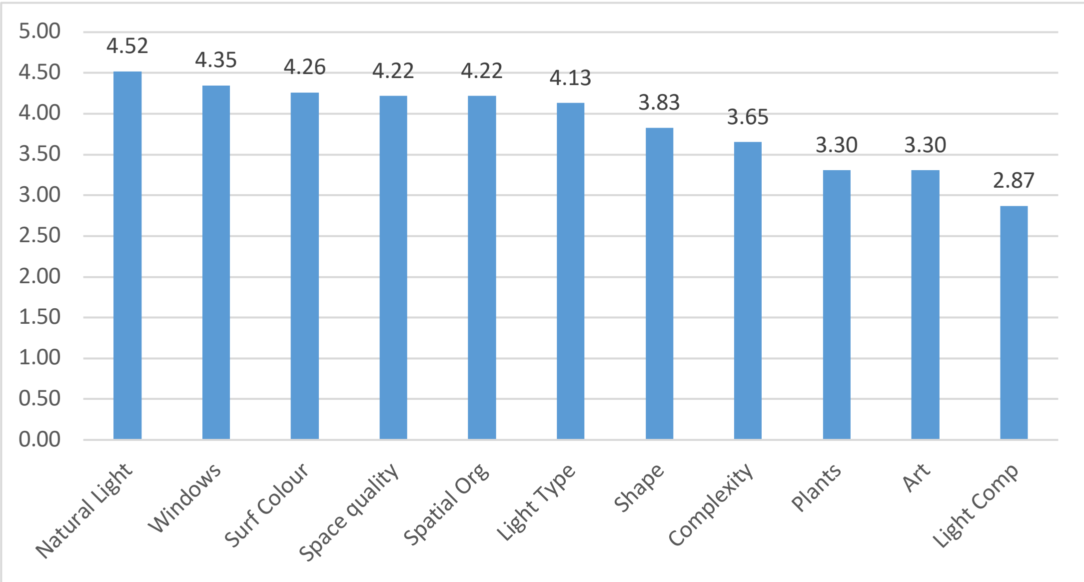


Figure 26. The result of the Preliminary survey (source: author)

Results

The result showed that all variables received respectful scores from 2.87 to 4.52. The highest is the Natural Light with score 4.52 ± 0.59, followed by the Presence of Windows with score 4.35 ± 1.11, the Surface properties (Colour, Texture & Pattern) with score 4.26 ± 0.92, the Space Quality and the Spatial organization shared the 4th rank with score 4.22 ± 0.85 and ± 1.00, then the Light type with score 4.13 ± 0.76, the Sense of Shape with score 3.83 ± 0.8, the Complexity of the Visual elements with 3.65 ± 1.07, then the Presence of Plants and Arts with the same score 3.30 ± 1.15 and ± 1.26. The last is Lighting Composition with a score of 2.87 ± 1.95. The complete data analysis can be found in Appendix C.2.

4.3. The Development Process

Guided by the results from the preliminary study, the development process began with the implementation of the selected visual variables into the application. They are:

- The Presence of Windows

- The Presence of Natural light
- Surface colour, and
- Spaciousness

Since natural light mostly appears in the presence of openings (i.e. windows or a skylight), the presence of natural light in the application was made dependant on the presence of Windows. For the window, rather than providing just two opposite conditions (absence/presence), it was considered necessary to add more layers to the window variables by incorporating 'Geometric-shape' factors to the Presence of the windows. In the preliminary results, the form and shape factor was ranked in 8th position, which made it initially excluded. The addition of geometric-shape factors offer more choice of window type/style for the user, though it also raises a few questions: How many need to be provided? How to choose the variations?

The Spaciousness is multi-variant influenced by factors such as the spatial dimensions, the surface colour, the density of the objects within the space and the crowds. In this experiment, the only spatial dimension that was included comprised the floor area and the ceiling height. The surface colour was featured separately. *Figure 27* shows the basic concept of implementing the visual variables.

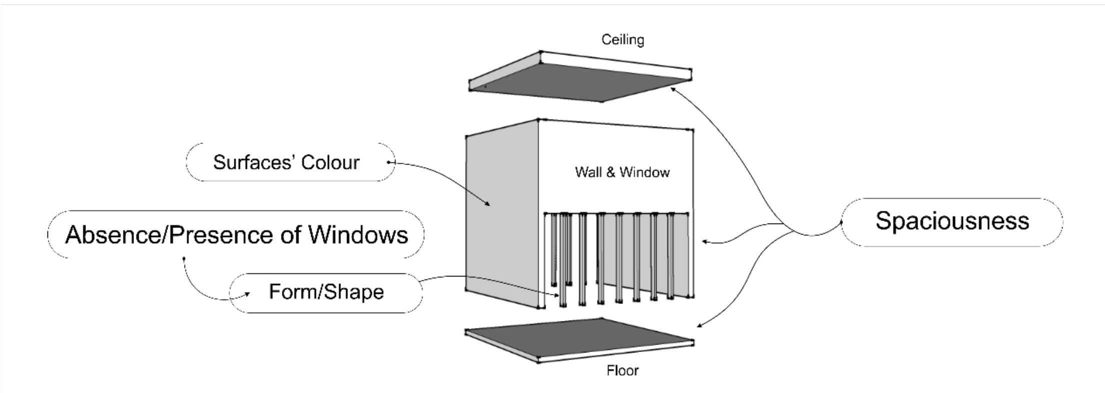


Figure 27. The Implementation of the visual variables into 3-D virtual space (source: author)

Determining the level of detail for the simulation is also crucial. Although people have the ability to make an interpretation of ill-fated information, maintaining a good level of detail is important. Depend on the purpose, level of detail does not need to be high. A too detailed brief is known to restrain the designer's creativity. The research decided to go forward with a generic approach for the visualisation, as the platform is considered to show the basic idea of the participants' tendencies, in such a way to leave more space for the designer to develop it further. The scene could be a representation of the participant's personal tendencies or consideration of others. For learning spaces that are used by many people, one or two artefacts may not represent all the users. Therefore, it needs to be in large numbers, when personal tendencies become collective and have more meaning.

To make the application accessible to a large scale of participants, there are several things that need consideration in the design:

- The application needs to be easy to use by participants with various skill levels, from the users to the designers. (anyone)
- It needs to be able to be accessed by participants located in different places. (anywhere)
- Its usage in the early stage of the design process also needs to be considerate, since the building design has not yet reached a specific form, where no sketch has been produced. Thus, the virtual environment is context-less, as it does not have a specific site or building shape that restricts the form and scale.
- It must be easy to set up, with minimum costs wherever possible.

4.3.1. The Virtual Learning Space

The central feature of this study is the three-dimensional Interactive Virtual Environment that enables the layperson to create a scene as an artefact while generating preferences data. Interactive Virtual Environment (IVE) has been around for decades with the release of a number of commercial 3D games in the early 90s, and steadily the design industry implements it into the design process. Despite some studies found it as more preferable to other media (Rafi, Mat Rani, and Rani 2010; Peng et al. 2010), the implementation of the IVE is not very straightforward thus never really reach the population. However, the latest development of VR headsets like Oculus Rift and a number of cheaper alternatives have open many possibilities, including to use the technology to conduct an online visual assessment with the public. However, at the time of writing, the use of a VR headset has not yet accessible to the larger share of the population due to the demanding hardware requirements and affordability. Since this study aims to reach as many people as possible, the Desktop 3-D Virtual Environment is envisaged as the feasible option to be accessed through Personal Computer devices.

The Enclosure

A room is constructed by the physical elements enclosing it, known as the floor, wall, and ceiling. In some cases, the elements are transparent. In another case, they are very rigid. The basic design for the learning spaces has a rectangular floor for several reasons:

- A room with a rectangular shape is nearly everywhere in many buildings.
- A rectangular shape is parametrically easier to control.
- The platform is designed to be used in the early stages, hence it is wise not to overcomplicate the room's design.

The default floor area is 8 x 8-meter square size, which is the standard proximity for public space according to Hall (1988) is 3.6 – 7.6 meters. The wall is 8m tall, with a default ceiling height of 3m. The enclosure elements (wall, floor, and the ceiling) are parametrically scalable and accessible using three sliders that represent the sides of the floor area (X and Z), and the ceiling height. All surfaces were given a neutral white colour.

The Outdoor Environment

There is no doubt that the environment on the outside of the windows will influence the participants. The complexity of the visual environment has been identified as influential for preferences (Kaplan and Wendt 1972). Just like the use of the furniture in this simulation, it is necessary to create a surrounding environment that is not deflecting too much attention for the participants. The early iteration of the Alpha version had totally ignored the surrounding environment and left it blank. On an internal test, the tester felt disorientated by the absence of the outdoor environment, thinking that the learning space was somehow floating above the cloud. The next iteration included the ground without any elements on it and made the impression that the learning space was floating above sea level. A generic urban environment was then created for the third iteration *(Figure 28),* which provide a subtle urban context for the learning space.

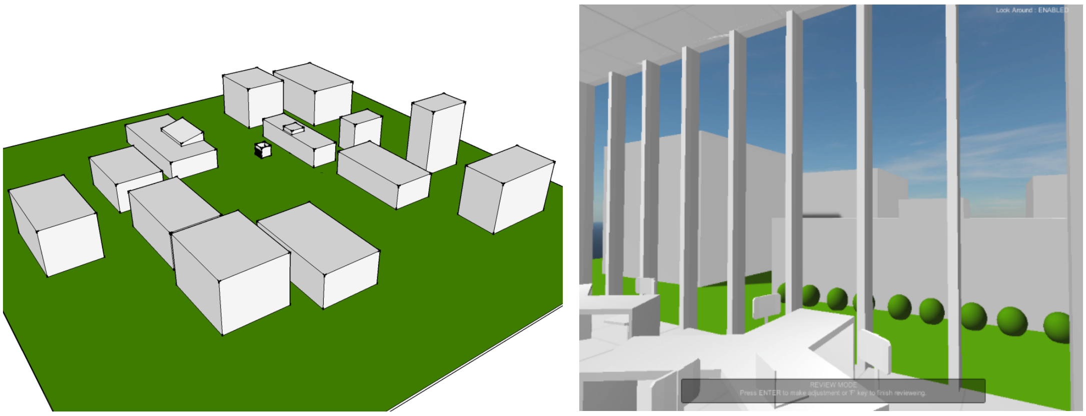


Figure 28. The generic urban landscape (left) and the view from the inside (right) (source: author)

The Agent

The camera position was set 170cm above the floor. It was attached to a dummy character that can make the movements as a person does and tilt its torso to look around. Fortunately, Unity 3-D with an asset called Character Controller that can be imported into any project and be used to navigate through the interior space. On a Personal Computer, the movement can be controlled using a keyboard and mouse, which is common for a 3-D game. The participant can choose to use either W, A, D, and S, or the Arrow Keys. In navigation mode, the mouse is used to look around/change direction. By default, the character can do basic movements, such as move forward-backwards, shift and turn left-right, jump, and look around. Few modifications in the scripting were required to make it suitable for the application. The modification will use the Spacebar to switch between Navigation Mode and Edit Mode. In the Edit mode, the look around feature will be disabled to enable the Agent to reach the sliders that appear on the screen.

Designing from inside-out has been discussed on various occasions. A significant contribution was a remark by Frank Gehry:

> *" …. I design from the inside out so that the finished product looks inevitable somehow. I think it is important to create spaces that people like to be in, that are humanistic".*

Emulating a daily experience is something this experiment is trying to achieve. To do that, participants can only view the simulation as a first-person view. There is no option to change the mode to different viewpoints, such as bird's-eye view or worm's-eye view.

Although a few will find it limiting, it is very common in many 3-D games. Also, the participant can move around freely in the virtual environment rather than be stricken at one position, or on a pre-defined track.

The Visual Cues

Without visual cues, it is easy to get lost in the virtual environment. The use of visual cues can vary from showing the direction, the function of the room (i.e. chalkboard for a classroom) and the sense of scale. In the p-VE, the visual cues for scale are provided by the surfaces of the floor and the ceiling that features a subdued 1-meter grid texture. Although the furniture factor did not make it into the application, in the Alpha version a transparent study desk and chair were included as a *visual-cue*. After the Piloting test, the updated version (Beta 0.1.) included a more complex furniture set, which will be discussed later. *Figure 29* shows the appearance of p-VE presentation layer in Alpha (left) and Beta versions (right).

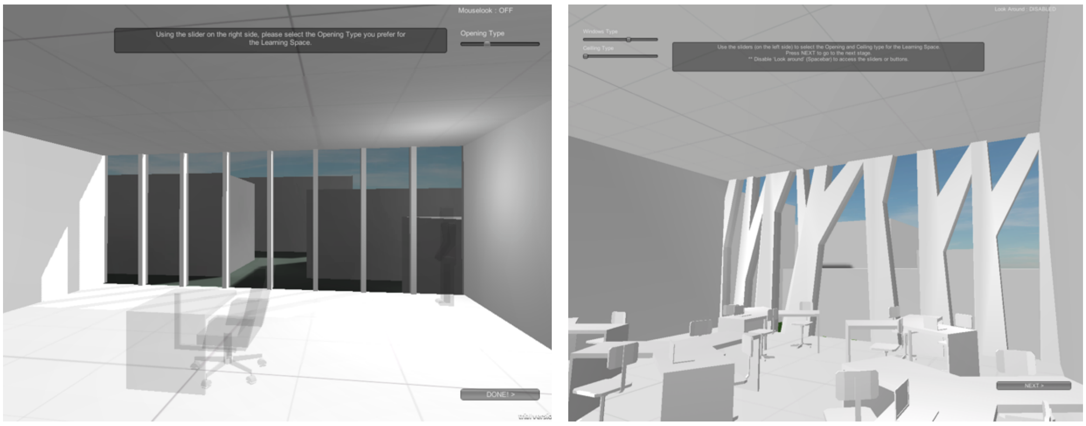


Figure 29. The visual cues in the Alpha version (left) and Beta version (Right) (source: author)

4.3.2. The Alpha Version

The Alpha version is the pre-released version that needs to pass a test prior to the experiment. The development of the alpha version started after a prolonged test confirmed that the chosen development tools are feasible to develop the application. After numerous attempts to connect with the online database, and it finally proving fruitful, it marked the assurance that the application can communicate with the online database (Parse). Few prototypes were produced to find a working scenario.

The 3-D environment is the main feature in the application *(Figure 30),* in which the participants will be able to navigate themselves and alter the appearance of the surroundings to correspond with the given task. The default appearance resembles a generic neutral-coloured space with no-windows. A squared-shape room is used due for two reasons: Firstly, it is easier to accomplish based on a technical viewpoint. Secondly, the square is a very common shape for interior spaces.

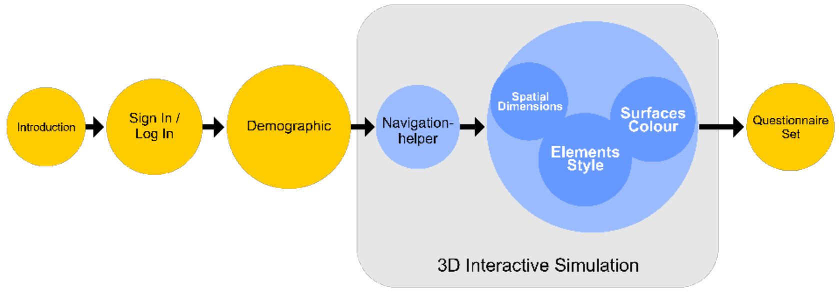


Figure 30. The workflow of the Alpha version
(source: author)

The Workflow
After several prototypes, the first working version of the application consisted of eight sections. They were:

1. *Introduction* page. This welcoming page presents the participants with a brief explanation regarding the purpose of the study, the tasks they need to complete, the right to terminate the experiment at any time, and contact details of the researchers.
2. *SignUp/Login*. Before proceeding into the application, the participants will need to create a unique UserID and password to access the application. This ID will be required every time they need access to the application.
3. *Demographic/User Profile*. User Profile is designed to collect the participant's basic demographic data. In the user profile section, the participants are asked about gender, occupation, and location. Gender is either female or male. The occupation is either student, design student, designer or other. The Location can be the United Kingdom, Japan, Indonesia or other. Afterwards, the virtual learning space appears.
4. *Navigation-helper*. Upon familiarising themselves with the 3-D environment, a pop-up appears to guide participants with the navigation and introduce some function keys. Using the navigation keys, they can explore the space and look around. Once

they feel comfortable with navigation, they can go to the next section to complete the tasks.

5. *Spatial Dimensions*. The default floor area is an 8 x 8-meter square size, with ceiling height 3 m. The enclosure elements (wall, floor, and the ceiling) are parametrically scalable and can be changed using three sliders that represent both lengths of floor area and the ceiling height. The floor area is sizeable from 2m to 16m each side, while the ceiling height can be changed from 3m to 7.5m. These dimension ranges were determined after conducting several trials to find the right balance between the scale and the proportion. The result of the experiment can be used to identify the default dimensions for the future version.
6. *Wall Colour*. The default colour is white. The participants can alter the colour using three sliders that represent Red, Green, and Blue values. Due to technical limitations, it was only the wall surface that was changeable in this version. All other surfaces (ceiling and floor) will be made available in the next iteration. Although in the real world, most surfaces use CMYK (Cyan, Magenta, Yellow, and Black) that is paint-based, Unity 3-D only supports the RGB colour system, which is a commonly used system for the visual display unit.
7. Window Style. Responding to the inclusion of Geometric shape as discussed earlier in section 4.3., six window variants were prepared for the participants *(Figure 32).* The default is a condition with the absence of windows. From here, the participants can choose five other variations. The reference for the number of the provided styles was Nassar's study in a preferences study of architectural houses, in which he provides six variations of house style (Nasar 1989). The style category is not derived from particular architectural styles (traditional, deconstruction, post-modern, etc.), but rather split into two, *Popular* Styles and *High* Styles, as discussed by Stamps and Nasar (1997). The high style has features such as eccentric, atypical, while the popular style has a more conventional geometric form *(Figure 31)*.

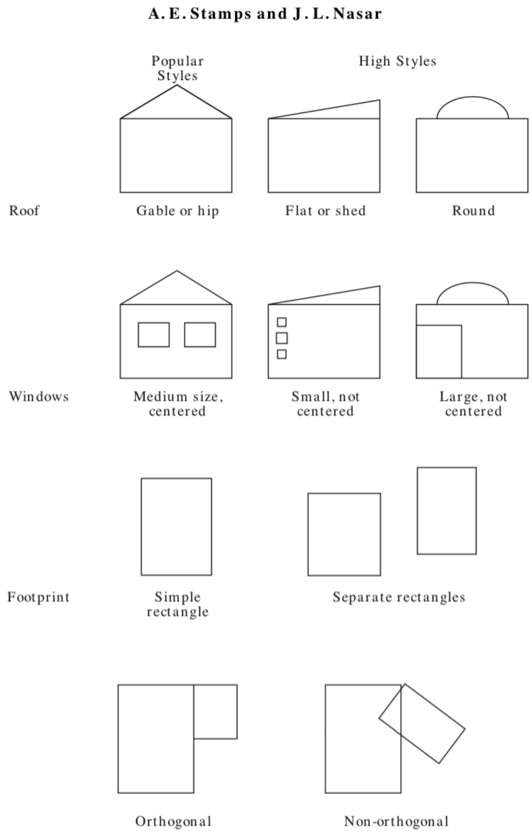


Figure 31. Popular and High Styles
(source: Stamps and Nasar, 1997)

The p-VE is a flexible platform that can adapt to different scenarios and projects. The designer as a researcher can include their own windows shape for the platform. For this version of p-VE, the author decided to produce six variations for the participants to choose from, the same number as Nasar's study. The inspiration was derived from various interior commercial spaces including offices, learning spaces (listed below).

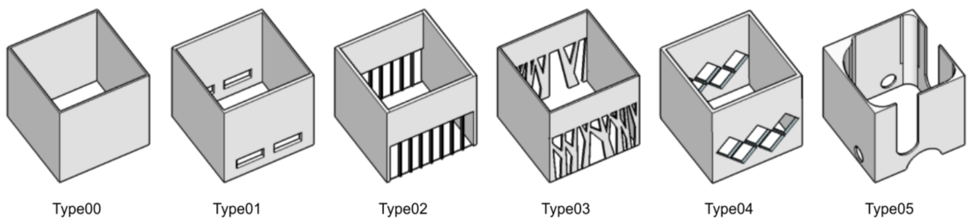


Figure 32. The Windows Styles
(source: author)

- Type00 is the default condition where no opening is present. Theoretically, this will be the least preferred in comparison to other condition where the window is present.
- Type01 is an enclosure with two small windows. This minimalist and institutional-looking style is common in the modern era and remains popular.
- Type02 is an enclosure with large vertical openings that occupy most of the wall. Looking from the inside-out, this formal looking style will reveal a large part of the surrounding environment to the occupant.
- Type03 is derived from Toyo Ito's design that features a form of natural elements while maintaining the large opening area for the natural light intrusion.
- Type04 is adapted from the Diamond building at Sheffield University. At the time of writing, this learning facility is one of the most recent developments in the city. The shape of the windows is intriguing and can be seen nowhere else in the surroundings.
- Type05, the last style, is a curvy enclosure with circular windows that looks like futuristic design, much like an imagined spaceship's windows. This style is a representation of an informal and playful design.

The variations were sorted based on the author subjective valuation of their collative property qualities i.e. as minimal-complex or institutional-playful. The expectation is that the participants' can review the space from the inside-out, and choose the window shape they prefer. Since the participant does not have access to the background information their decision is solely based on the visual information.

Depend on the project and the surveyor's decision, the p-VE can have a different set of windows style. The limitation to include the style of the window is that there are too many variations out there that can be included in this platform, and with only a few variations will not satisfy everyone.

8. Questionnaire. In this version, the questionnaire section is dedicated to the Usability test to evaluate the p-VE. The questionnaire page appears after the participants complete the tasks and require responding to a set of statements related to their recent experience in using the application.

9. *Terminated*. At this point, the application will send the questionnaire and responses to the online database and then terminate the application.

The Usability Test

The usability test takes place in the Questionnaire section of the p-VE. The first three statements (Q01 – Q03) are the three components adopted from After-Scenario Questionnaire (ASQ) to investigate the participant's subjective evaluation regarding the p-VE usability:

1. I am satisfied with how easy it is to use the system (Q01).
   This simple statement is easy to comprehend and is not trying to overcomplicate the purpose of the application. The participants just need to make a general assessment based on their experience while using p-VE.
2. I am satisfied with the support information while completing this task (Q02).
   In the design of p-VE, the support system is provided with the introduction, the navigation-helper, and the instruction to complete each task.
3. I am satisfied with the amount of time it took to complete this task (Q03).
   The general assumption suggests a survey should not consume too much time, approximately 10 – 15 minutes. The p-VE also has a timer to count the amount of time spent by the participant during the experiment.

Furthermore, four more statements were added to investigate the participant's opinion regarding function usability in the p-VE (Q04 - Q06).

4. This tool allows me to express my preference for spaciousness adequately (Q04).
5. This tool allows me to express my preference for Window Style adequately (Q05).
6. This tool allows me to express my preference for wall colour adequately (Q06).

And the last statement was

7. I believe that this tool can develop designer awareness of users' visual preferences (Q07).

The questionnaire also provides a text-field for the participants to leave written comments or feedback. At the end of the questionnaire, the participant will be offered the chance to receive any updates regarding the study. To do so, they can leave an email address in the available text field.

4.4. The Piloting Test

Before conducting the piloting test, the alpha version was checked to ensure the platform work properly. The internal procedure was conducted among three participants accessing the platform from separate locations. A link was sent through email where the participants accessed the platform, did the tasks and sent the data to the Cloud database. The data received in Parse was a confirmation that the platform is working and ready for larger participants in a Piloting test.

Once The Piloting test was conducted by inviting more participants to assess the application's feasibility and usability under the experiment scenario. The participants can be anyone interested or affected by the development of the learning spaces, namely the students, lecturers and staff of higher education institutions.

- To test the application's feasibility for the experiment scenario by involving participants from various backgrounds, from different countries (anyone, anywhere, anytime) to access the application and express visual preferences, it was crucial to find out how p-VE performs in various countries with different connection speeds.
- To investigate the user subjective evaluations on the usability of the application, by responding to the After-Scenario Questionnaire after completing the tasks, the participants need to respond using a Likert-scale, either to provide a disagreeing, agreeing or neutral (undecided) response.
- To invite the participants to leave comments and feedbacks for further development, the participants can leave written feedback using a fill-in form to give more freedom in expressing opinions.

4.4.1. Procedure

To make the p-VE accessible through the Internet, the HTML files generated by Unity3-D were uploaded onto a server. For this experiment, the files were copied to a Dropbox Public folder that can be accessed using a web-browser with a Unity web-player installed. The invitations were distributed through email and social media to a limited number of higher-education students and design professionals for valuable feedback. Using a link attached to the invitation, the participants can access the Alpha version through a web browser, e.g. Explorer, Chrome, Firefox. Once the application runs on the system, they need to follow the instruction steps in the application and complete the piloting test as described.

Nineteen subjects participated in the piloting test and accessed the application. However, two entries were incomplete leaving only seventeen for analysis. The participants' consisted of 4 females and 13 males, of which fourteen are students (including four design students), and 3 are professional designers. Six participants based in the UK, seven in Indonesia and 4 in Japan. During the piloting test, nineteen Scenes from the participants were received and stored in the online database, which indicated the application is working properly and feasible to support the participants in completing the Scenario. The fact that some of the participants were from a developing country also confirmed its feasibility to work with less-sophisticated internet infrastructure.

4.4.2. Data Analysis

Reliability and Validity

The data then processed in SPSS for reliability analysis, in which the reliability coefficient (Cronbach's alpha) for the questionnaire set was determined to be highly correlated with α= 0.82 based on seven items (Q01-Q07). Therefore, the usability-test instrument in the p-VE has shown to be highly reliable. Further test also identified that all items used in this study are valid, shown by the Corrected item-total Correlation value of each item (Q01-Q07) > R table (0.4821).

Data Normality

Based on the comparison of mean, median and mode values of items Q01-Q07, it is identified that all of the items are skewed to the left, where the mean value is larger than the mode. If the skewed distribution is being considered, the median should be used rather than the mean. However, for the Likert-scale data, usability experts (Sauro 2016; J. R. Lewis 1991) suggests the use of mean and standard deviation is acceptable, as long it not to be used to make interval/ratio statement. More results of the piloting test can be found in Appendix D.

4.4.3. Result and Finding

The Usability test showed that participants were moderately in favour of the usability of the tool (Figure 29). The score was 4.47 (scale 1 to 7) for easy-to-use (Q01), 4.76 for the satisfaction of support information (Q02), and 5.18 for the satisfaction with the amount of time to complete the task (Q03), which is the highest among the three components.

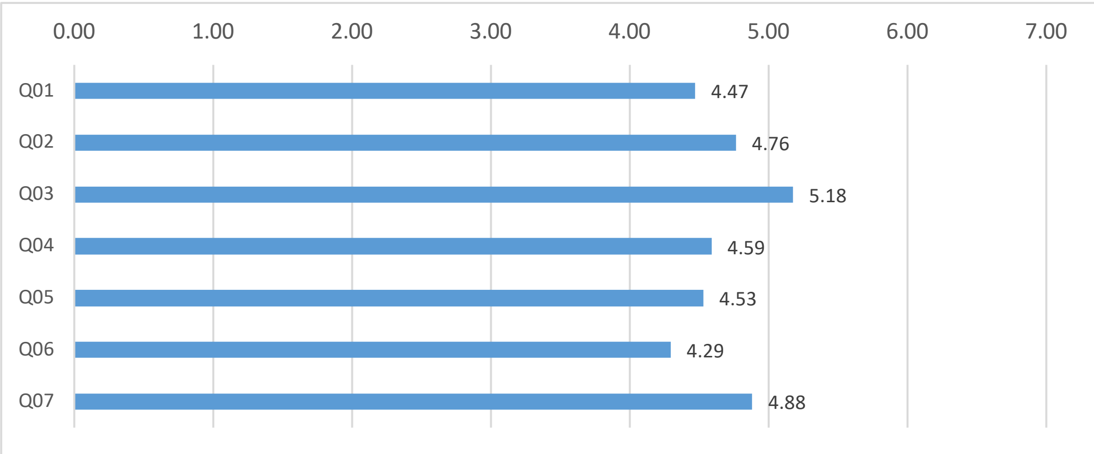


Figure 33. The usability-test results
(source: author)

The participants also moderately agreed on the function usability of the p-VE, in which it received 4.59 for spaciousness feature (Q04), for allowing to choose Window Style adequately (Q05) with score 4.53, and for allowing to express wall colour (Q06) with score 4.29.

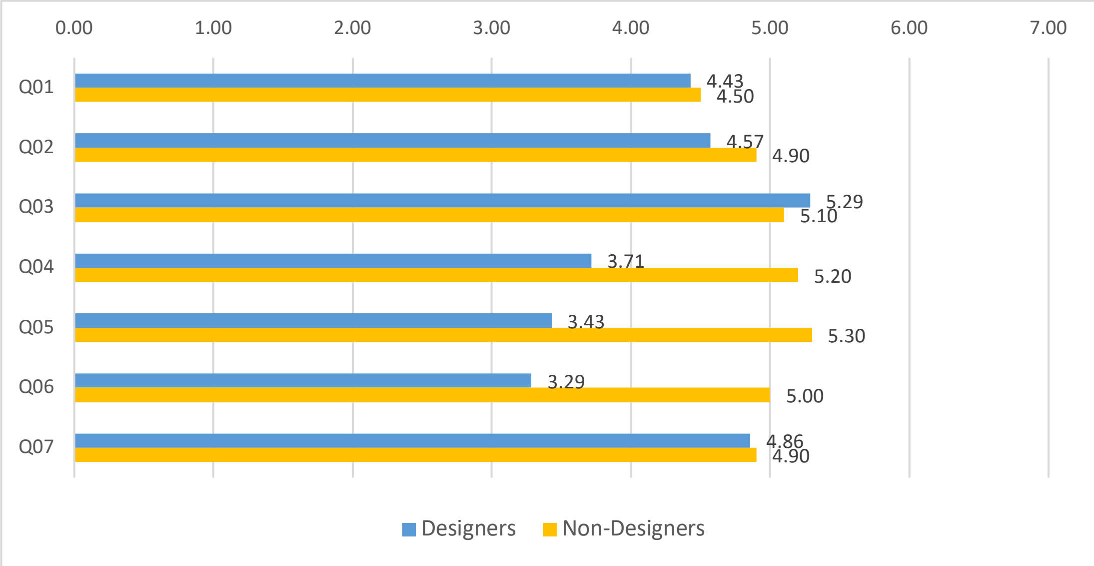


Figure 34. The usability-test results of Design and Non-design Background (source: author)

When the participants were separated into two groups based on the design experience, the designers' group mean-rating for the specific usability (Q04-Q06) were significantly lower than the non-design group (Figure 34). Along with the usability test, a text field (Q08) was provided for participants to write comment or feedback. The written feedback mentioned various issues to improve the p-VE before the main experiment. Some of them are:

- There should be more object variations to choose from for the Opening and Ceiling type.
- Technical problems during the experiment.
- There should be alternative methods, such as using a palette rather than sliders, to choose the preferred colour.
- There should be the ability to use different colours on each surface of the wall.
- There was a lack of Lighting effects.
- To include more furniture in the virtual environment.

In addition to the data from the questionnaire, p-VE also received preference data from 17 participants. More results of the piloting test can be found in Appendix D.2. At this stage, the Visual Analytic had not yet established or revealed more detailed results of the visual preferences data.

Conclusion

The piloting test has demonstrated the feasibility of the proposed design in a way that it was accessible online by the participants from various locations and allowing them to complete the tasks as required by the scenario. The data analysis showed that the usability-test instrument is reliable and valid to measure the perceived subjective evaluation for the p-VE on all item (Q01-Q07), whereby the proposed method passed all of the evaluation. Although, nearly all items except Q03 received the mean score less than 5, and the design group scores on the function usability (Q04-Q06) were significantly lower than the non-design group, presumably since the designers have more complex requirements and have experienced in using other commercial applications. Expectedly the revised version can improve the result.

4.4.4. The Beta Version

Version 0.1

Based on the Piloting test and the feedbacks, some revisions were implemented in the updated version, with code Beta 0.1. The main differences compared to the Alpha test version are:

1. The full-screen mode. This corresponds to a problem that occurred on the Piloting test, where the application's resolution was not covered by some of the participant's display on the computer. Since the author was unable to automate the process, the participant needed to do it manually. A message will appear after the introduction dialogue box to guide the participants to enter the full-screen mode with a few clicks on their mouse or touchpad.
2. All visible surface colours of the enclosure are now coloured modifiable. As previously mentioned, only the wall colour can be altered on the pilot version. In the final version, participants will be able to change the colour of the wall, ceiling and floor to their preferences.

In response to the feedbacks:

3. One of the major changes is the addition of the Colour pallet, which shows the preview of the colours rather than mixing the colour using sliders. The colours are retrieved from favourite colours for Nursery learning spaces ("Cloud Wall Stickers

for Nursery" 2015), which consist of 48 colours. The participant can review the colour they have selected and the applied colour on the surface. The participants can still mix a custom colour whenever desired. The colour list can be found in the table in Appendix B

4. Furniture within the space. Feedback from the Piloting test suggested putting more furniture (i.e. study desks) within the space. The main reason is to help the participants build the perception of the function of the interior space and act accordingly. Although the furniture did not make it in since the beginning, the presence of furniture is indeed the matter that has been much considered since the pilot version, though it had to wait due to programming issues. As well as on the previous versions, the main purpose of the furniture is for visual cues, i.e. scale.
5. Ceiling Style (variation) was not included in the Piloting test and was only considered upon receiving feedback from the participants. Like the Window Style, the variations were either typical or atypical, which varied between minimal/complex, conventional/playful and common/avant-garde. And, like the Window Style, there are six variations for Ceiling *(Figure 35)*.

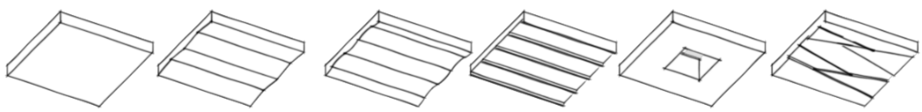


Figure 35. The ceiling Style
(source: author)

a. The default is the flat ceiling (CType01). This type of ceiling is a standard ceiling that is found in almost all buildings. It does not feature any variations other than just being flat. It reflects a sense of formality, efficiency and institutional-looking, but is also popular among minimalists.
b. The second type is a zigzag ceiling (CType02), a more playful version of the planar ceiling that has multiple panels composed diagonally.
c. The third one is a Wavy ceiling (CType03), which is informal and playful. This type of ceiling is rarely to be found in educational institutions.
d. The fourth one is a planar ceiling with exposed beams (CType04). This ceiling has a more institutional feel and is rigid.
e. The fifth is a flat ceiling with large skylight (CType05). This type of ceiling is popular in the area with little sun exposure.

f. The sixth ceiling has a design that is highly atypical compared to the other styles (CType06).

The piloting test found that a relatively high percentage of participants (21%) have chosen the condition of no windows for the learning spaces, which goes against the common conception that occupants would prefer a windowed room. Therefore, the following changes were implemented to address the issue *(Figure 36).*

6. The addition of a Timer to record the time spent by the participants to complete the experiment.
7. The addition of a *Review* section. After completing the task the respondents can reflect on their creation and make final decisions before submitting it.
8. The addition of a *Confidence Rating* feature to allow users to indicate how confident they are in expressing their visual preferences using p-VE. Thus, the updated version changes the flow of work with the inclusion of *Review* and *Confidence Rating*.

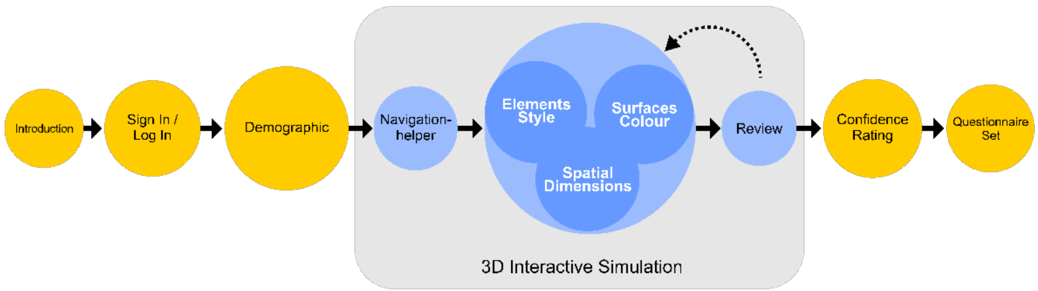


Figure 36. The workflow of the Beta 0.1 version (source: author)

The full version of Beta 0.1 workflow can be found in Appendix A, along with a link to an online video. Parts of the visual scripting can be found in Appendix I. The full visual scripting cannot be featured due to its numbers and complexity.

Version 0.2

The Beta 0.2 is a variant of p-VE used for the Second stage aimed at the design participants *(Figure 37).* Overall, it is similar to the Beta 0.1 version, with few modifications in the flow of work by removing the Demographic section and the Confidence rating.

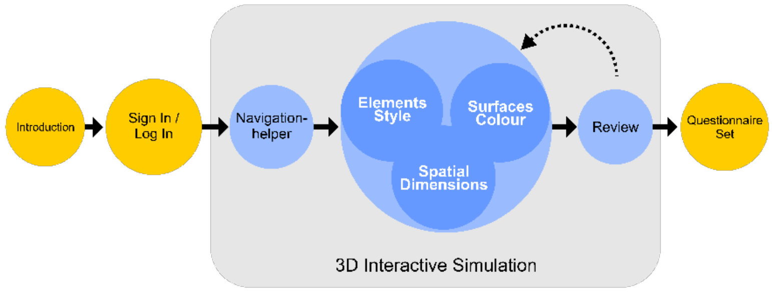


Figure 37. The workflow of the Beta 0.2 version (source: author)

The Beta 0.2 version also features a new questionnaire set, which will be further discussed in the next chapter. The statements are:

1. The provided Visual Preferences Document (PDF) is easy to understand (Q01).
2. The colour preferences data is influential for decisions I made at the 2nd stage (Q02).
3. The Spatial dimension preferences data is influential for decisions I made at the 2nd stage (Q03).
4. The Window & Ceiling type preference data were influential for decisions I made at the 2nd Stage (Q04).
5. The Visual Preference data helps in understanding the user' characteristic (Q05)
6. The Visual Preferences data helps in understanding the design direction (Q06)
7. The Visual Preferences data restricts design creativity for developing design proposals (Q07).
8. I am aware of the Visual Preferences data and will use it as guidance for the design development process (Q08).
9. I am aware of the Visual Preferences data. However, I have a different idea for the development of the design (Q09).
10. Other things (not mentioned above) I can learn from the Visual Preferences data (Q10).

System Architecture

At this stage, the design and implementation of the p-VE have evolved considerably from the initial design. The figure shows the system architecture of the p-VE describing the fundamental structure comprises the elements and the relationships between them.

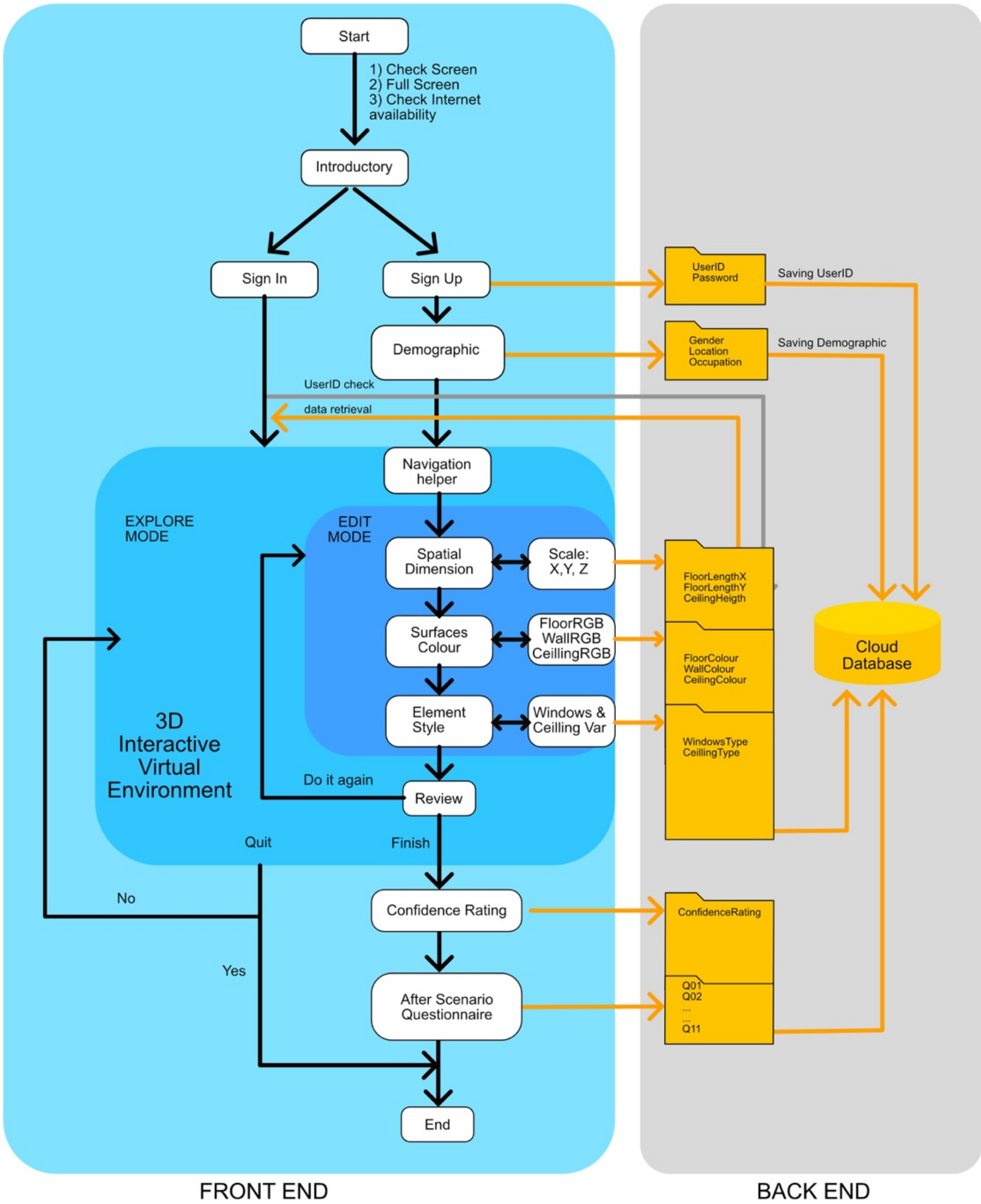


Figure 38. System Architecture
(source: author)

Chapter 05
The Experiment Design

As previously mentioned, the experiments in this study have two purposes: a) To evaluate the usability of the p-VE, b) to collect preference data from the participants. Collecting users' preference data through the platform will be meaningless if the participants think the p-VE is not usable. A usability test is included at the end of the p-VE, which appears after the participants complete the tasks. Initially, the study was planned to be conducted in one stage, rather than two. After reviewing the result of the piloting test, in which the designers' evaluation to function usability were below expectation, a second-stage experiment was then added.

5.1. The First Stage / The Main Experiment

In the design and implementation process of p-VE, a Piloting test had been carried out on a limited group of participants. In many aspects, the design of the first stage is the same as the Piloting test. The main differences were the scale of the participants and the version of p-VE used for the experiment. Therefore, the overall procedure also refers to the new workflow of the updated Beta 0.1 version discussed in the previous chapter.

As for data gathering, the first stage experiment collected the expressed visual preferences of learning spaces from as many participants as possible, using the proposed method. Along with data collection, the feasibility was further investigated with a much larger group of participants from various backgrounds, from different countries (anyone, anywhere, anytime) and with the capability to handle t data traffic. With a larger group of participants, the subjective usability test is expected to generate a more reliable result. And hopefully, better mean-ratings in many aspects, since various updates have been implemented in the Beta 0.1 version.

5.1.1. Participants

Purposive sampling was used to reach a large number of participants with various backgrounds and skills, anyone who is interested or affected by the development of the learning spaces (i.e. the students, lecturers and staff of higher education institutions) can join the experiment, regardless the location, gender, or occupation. The implication of the sampling technique, the proportion of the demographic groups, gathered through the survey were not in the same proportion. A few measures have been added to evaluate participants performance during the experiment, they are:

- A Timer to record the time spent by the participants to complete the experiment.
- A Review section to allow participants to view the scene and make the last decisions before submitting the scene they have created.
- A Confidence rating. The participants who have higher confidence score presumably do adequate effort to create a result that satisfies them.

5.1.2. Procedure

Invitation

Principally, the procedure in the first stage has no significant differences to the piloting-test. The invitations were sent through email and social media consisted of a brief introduction of the purpose of the study, and a link that directs the participant to the p-VE. The first-stage experiment used the updated version (Beta 0.1). An Introduction will prompt to briefly introduce the purpose of the experiment. The next step is a Signup page, where participants can either Sign Up or Log In. The steps for the first stage can be seen in the figure below *(Figure 39).*

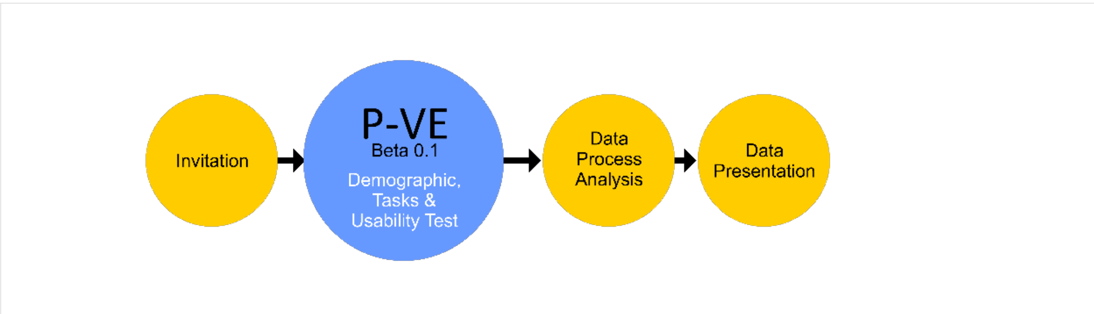


Figure 39. The steps of the first-stage experiment
(source: author)

The Tasks

An Introduction briefly explains that the virtual learning space is intended for 20-40 occupants, and the task for the participant is:

"Express your preferences on these following properties: (1) Windows and Ceiling Type, (2) Spatial dimensions (3) Ceiling/Wall/Floor colour which you think are favourable for learning space."

After the Signup/Login page, the Demographic page requires the participant to respond to a few questions regarding gender, occupation, and location. A dialogue box appears to show the navigation keys in the virtual environment. After completing the demographic data, and practising the use of the function keys, the participants can start the tasks by moving to the next section:

- Use the sliders (on the left side) to select the Opening and Ceiling type for the learning space and press the NEXT button to go to the next stage.
- Use the sliders to find the preferred spatial dimensions for the learning space. The first two sliders are for the area size (floor area), the third is for the ceiling height, and then press the NEXT button to go to the next stage.
- Click the icon on the left to expand a colour table for the ceiling, wall, and floor. After that, participants can select one of the colours from the table or use R/G/B sliders to mix a specific colour. They can press NEXT to go to the next stage *(Figure 40).*

Figure 40. The presentation layers of spatial dimensions (left) and surface colour (right) tasks (source: author)

Usability Test

The design of the usability test experienced few minor adjustments due to the revisions of the p-VE into Beta version. The final version of the Usability test in the Questionnaire section are as follow:

1. I am satisfied with how easy it is to use the system (Q01).
2. I am satisfied with the support information while completing this task (Q02).
3. I am satisfied with the amount of time it took to complete this task (Q03).
4. This tool allows me to express my preference for spaciousness adequately (Q04).
5. This tool allows me to express my preference for window and ceiling type adequately (Q05). The statement has been revised due to the addition of the Ceiling Type.
6. This tool allows me to express my preference for colour scheme adequately (Q06) The statement has been revised due to the addition of the Ceiling Colour and the Floor Colour.
7. I believe that this platform can develop designer awareness of user's Visual Preferences (Q07).
8. I would like to suggest a few things for improvement (enter text on the right field): (Q08).

5.1.3. Data Process

The Data Process collect the data from the cloud database. In this study, the available technology was Parse, which allows the users to download the database in JSON format. Depend on the analysis method, it needs to be converted to the intended application. The application must allow the data cleaning process, and to conduct a descriptive statistic. The data cleaning process will look at any mistakes caused by the inputting process, especially at the questionnaire stage. Section 5.3 explains for the data analysis required.

5.1.4. Visual Preferences Document

The visual analytic document needs to be prepared for the second stage, in which the participant needs to access it. The purpose is to inform the designers of the first-stage results as clearly as possible. There are two potential approaches to process the data: as a

Scene and as visual variables. As a scene means to view the scene as the participant sees it in the 3-D simulation. The second approach was carried out by developing infographics on the visual variable results, which clearly show the Participant preferences for the Surface colour, the spatial dimensions, and the Element style.

5.2. The Second Stage

To investigate how the professional designers will respond to the visual preference results, a second experiment needed to be conducted. The decision was initiated by the Piloting test results, in which it was shown that the design group found it inadequate to express their preferences. The findings raised the fourth research question: How will the professional designer respond to the results of the visual preference gathered through the proposed method? The second stage was designed to address this issue. Considering that the first stage experiment, involving a large number of participants, may influence their design decision in any way.

5.2.1. The Participants

Professional designers (architects and interior designers), who have at least two years of educational or professional experience, were invited to participate in the experiment.

5.2.2. Procedure

Invitation

Like the First stage, the participants were recruited through invitations that link them to the p-VE. For the participants who have never been in any of the experiments, the link directed them to Beta 0.1 for the first stage. Prior to the second stage, all designers received a PDF document consisting of the Visual Analytic of the result of the first stage. Afterwards, they will be asked to carry out the Second stage. The task itself is no different compared to the First stage. The steps for the second stage can be seen in the figure below *(Figure 41).*

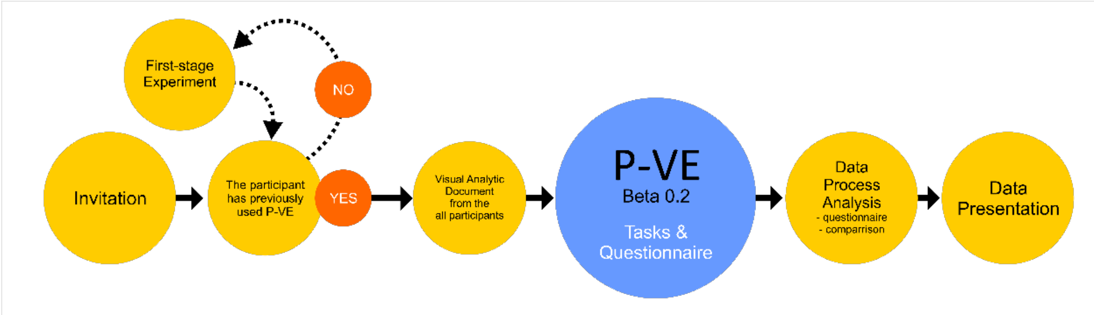


Figure 41. The Steps of the Second-Stage experiment (source: author)

The Tasks

Before proceeding with the experiment, the designers were given a Visual Analytic document consisting of infographics of the first stage results that had been collected from the participants. It consisted of all participants' Visual Preferences of Spaciousness, Surface Colour and Element Style. Having studied the document, the designers were then asked to do another session using the p-VE.

An Introduction briefly explained that the virtual learning space is intended for 20-40 occupants. The tasks for the participant is:

"Express your preferences of these following properties: (1) Window and Ceiling Type, (2) Spatial dimensions (3) Ceiling/Wall/Floor colour which you think are favourable for learning space."

After the Signup/Login page, the Demographic page requires the participant to respond to a few questions regarding gender, occupation, and location. A dialogue box appears to show the navigation keys in the virtual environment. After completing the demographic data, and practising the use of the function keys, the participants can start the tasks by moving to the next section:

- Use the sliders (on the left side) to select the Opening and Ceiling type for the learning space and press the NEXT button to go to the next stage.
- Use the sliders to find the preferred spatial dimension for the learning space. The first two sliders are for the area size (floor area), the third is the ceiling height and then press the NEXT button to go to the next stage.

- Click the icon on the left to expand a colour table for the ceiling, wall, and floor. subsequently, the participant can choose one of the colours from the table or use R/G/B.

Questionnaire

The second stage experiment used the Beta 0.2 version, which is similar to Beta 0.1. There are no apparent changes in the design of the application, except the demographic page was deleted, since the participant data had been collected in the first stage, and the questionnaire that carried out new statements was already crafted for this stage.

1. The Provided Visual Preferences Document (PDF) is easy to understand.
   The purpose of this statement was to investigate whether the infographic featured in the document was adequate and easy to understand (Q01).
2. The colour preference data is influential for decisions I made at the 2nd stage.
   The purpose of this statement was to investigate how influential colour preference data was to the changes made at the second stage (Q02).
3. The spatial dimension preference data is influential for decisions I made at the 2nd stage. The purpose of this statement was to investigate, how influential was spatial dimension preference data was to the changes made in the second stage (Q03).
4. The Window & Ceiling type preference data were influential for decisions I made at the 2nd Stage. The purpose of this statement was to investigate how influential the element style preference data was to the changes made at the second stage (Q04).
5. The Visual Preference data helps to understand the user characteristics.
   The purpose of this statement is to investigate whether the results from the first stage was adequate for the designer to understand the user characteristics (Q05).
6. The Visual Preference data helps in understanding design direction. The purpose of this statement is to investigate whether the results from the first stage were adequate for the designer to determine the design direction (Q06).
7. The Visual Preference data restricts design creativity to develop a design proposal (Q07).
8. I am aware of the Visual Preference data and will use it as guidance for the design development process (Q08).
9. I am aware of the Visual Preference data. However, I have a different idea to develop the design (Q09).

10. Other things (not mentioned above) I can learn from the Visual Preference data. This is a text field where the participant can leave written comments and feedback (Q10).

Like all the previous surveys, the professional designer needs to respond using a Likert-scale, ranging from ‘strongly disagree’ to ‘strongly agree’.

5.2.3. Data Process

Similar to the first stage, the data process collects the experiment results from the cloud database in JSON format. Depend on the analysis method, it needs to be converted onto the intended application. The application must allow the data cleaning process, and to conduct a descriptive statistic. The data cleaning process will look at any mistakes caused by the inputting process, especially at the questionnaire stage. The following section explains for the data analysis required.

5.3. Data Analysis

The two-stage experiment in this study generated two groups of data set:

a) Preference data gathered during the scenario i.e. virtual environment session, which consists of eight design variables: The Wall colour (48 components), the Ceiling colour (48 components), the Floor colour (48 components), the Floor Length X (15 components), and Floor Length Z (15 components), the Ceiling height (7 components), the Window style (6 components), and the Ceiling style (6 components). In total there are 193 components for the participants to choose.

b) Questionnaire data gathered after the scenario. The questionnaire consists of Likert Scale type questions, which assess the participants’ agreement over a variety of statements. In the first stage, the questionnaire consists of the Usability test to measure the perceived usability of the p-VE (7 items Likert Scale and 1 essay), while the second stage consists of 9 items Likert Scale and 1 essay. The data from the questionnaire will be checked and analyse for reliability, validity for each item, and descriptive statistics.

5.3.1. Data Reliability and Validity

The measurement of reliability in this study used one-shot, in which the result is compared to other questions in the questionnaire set or measuring the correlation between responses to the statements. Palmer and Hoffman (2001) infer that reliability as 'consistency of something that is repeatedly done'. However, this procedure can only be used if the instrument has the same scale for all items. The reliability coefficient (Cronbach's alpha) for the questionnaire set then can be determined using SPSS. According to Guilford (1956), the reliability coefficient categories are:

- 0.80 < 1.00 : Very high reliability
- 0.60 < 0.80 : High reliability
- 0.40 < 0.60 : Moderate reliability
- 0.20 < 0.40 : Low reliability
- -1.00 < 0.20 : Very low reliability

The validity of the questionnaire items is measured by correlating between the question score and the overall assessment score. In general, the higher the score, the likely a participant gets a question correctly. The relationship shows an item-total correlation indicates the performance of questions (Pope 2009).

- > 0.4 : Very good discriminating
- 0.2 – 0.39 : Good discriminating
- 0 – 0.19 : The question is not discriminating well

Another version is to compare the Item-total Correlation with r table:

- If the Item-total Correlation > r table and is positive, then the variable is valid.
- If the Item-total Correlation < r table, then the variable is invalid.
- If the Item-total Correlation > r table but with a negative value, then H0 will remain rejected and H1 accepted.

An item is valid if the Item-total Correlation has a positive value and equal or greater than the R table with 5% significance level, if the coefficient is less than 5% then the correlation is not significant.

5.3.2. Descriptive Statistics

The descriptive statistic is used to summarise the data set gathered during the experiment. Descriptive statistics are divided into measures of central tendency and measures of variability (spread). To measures the central tendency typically the mean, the median, and the mode are used, while variability includes the standard deviation, the minimum and maximum variables, and skewness.

5.3.3. Groups Comparison and Correlation

To investigate groups comparison and correlation the results of the questionnaire and the preference data will be considerate. That include the Wall colour (48 components), the Ceiling colour (48 components), the Floor colour (48 components), the Floor Length X (15 components), and Floor Length Z (15 components), the Ceiling height (7 components), the Window style (6 components), the Ceiling style (6 components), all the 193 components, and the top-voted component for each design variable.

Correlation test is used to test whether there is a correlation between demographic groups, and also the professional designer on both stages. The correlation coefficient criterion between variables is ranged from 0 to 1, with the following interpretation:

0.81 - 1.00	: Perfect correlation
0.61 - 0.80	: High correlation
0.41 - 0.60	: Moderate correlation
0.21 - 0.40	: Low correlation
0.0 - 0.20	: No correlation

If significant (sig.) value < 0.05, the correlation is significant.

Chapter 06
The First-Stage Results

6.1. Data Gathering

The first stage of data collection was carried out from April to June 2015 and from October 2015 along with the Second stage. The busiest traffic recorded was during the 2nd week (27th April – 4th May 2015) period *(Figure 42).* In average, all participants took 7.94 minutes to complete the first stage.

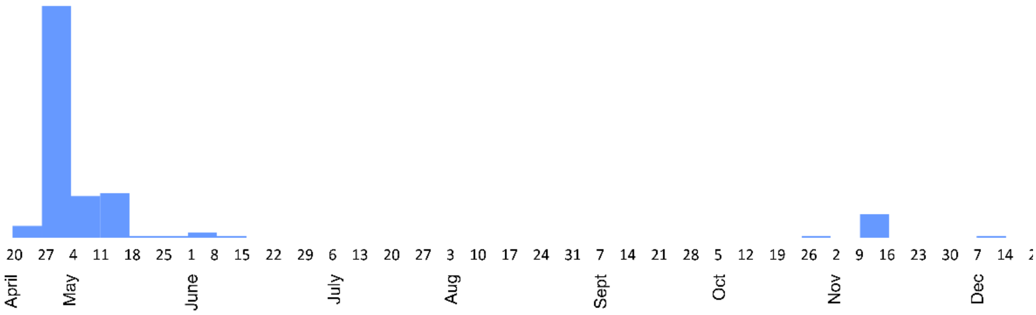


Figure 42. Data traffic during the experiment.
(source: author)

The data from *Parse* was downloaded in *JSON* format and converted into a Spreadsheet. Prior to the analysis process, each entry was coded based on the participant's Location, Gender, and Occupation. Some of the User Profile data needed a few adjustments. For example, some participants mentioned the city rather than the country for their location, thus, that could be problematic for the analysis purpose. The five countries mentioned for locations are coded as follow: Indonesia (coded as IND), the United Kingdom (UK), Japan (JPN), Thailand (THN) and Australia (AU). For gender, the code is either female (F) or male (M), while the Occupation is coded as S for students, DS for design students and D for Designers. Participants who did not specifically mention a specific location or occupation were given Other (O) code.

6.2. Participants

There are a total of 186 people participated in the experiment, which more than ten times over the piloting tests population. With the higher participation number, it was thus expected to give a more stable result. Since the experiment was distributed without specific requirements of demographic proportion (purposive sampling), the share between some of the demographic groups became greatly unequal, for example, the proportion of the Design and Non-design background groups.

On the gender category, one subject did not respond to the question. Eighty-two (44.3 %) participants are female, while the male participants numbered 103 (55.7 %) (*Figure 43*).

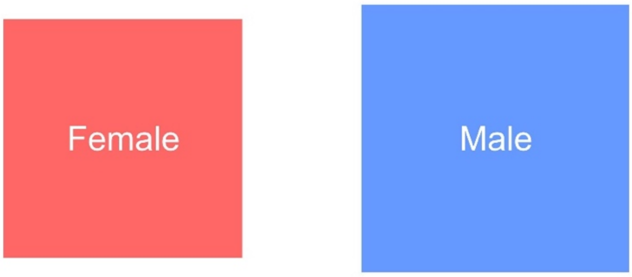


Figure 43. The proportion of participants based on gender.
(source: author)

Based on the location category, the majority came from Indonesia, with 135 participants (72.6%), followed by the United Kingdom with 36 participants, (19.4%), Japan 11 participants (5.91%), two from Thailand (1.08%) and one participant from Australia (0.54%). One participant did not specify the location (*Figure 44*).

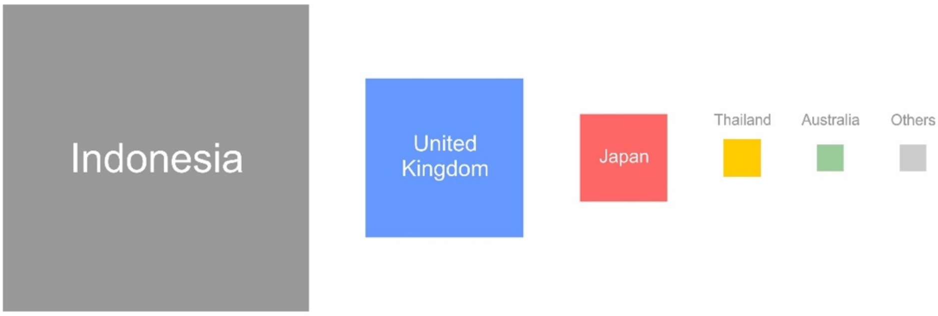


Figure 44. The proportion of participants based on location.
(source: author)

Based on the occupation category, the number students were 119 (64%) of all participants, of which 16 (8.6%) of them are from design education, either from architecture, interior design or product design. Professional designers accounted for 28 (15.1%) participants and those who do not fall into any of the categories (Others), numbered 23 (12.4%) participants (*Figure 45*).

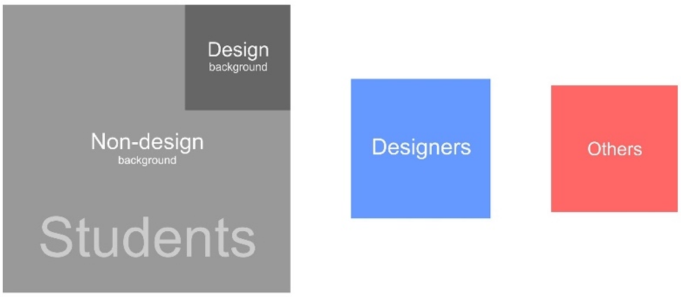


Figure 45. The proportion of the participants based on occupation.
(source: author)

6.3. Usability-Test Analysis

The test received only 121 responses out of 186 participants due to an error in the scripting. The problem was fixed swiftly. However, there were 66 participants left without any recorded data from the questionnaire. Although the pilot test has confirmed the feasibility, the first stage received a significantly larger number of participants.

Reliability and Validity

The piloting test has confirmed the reliability of the instrument with limited participants. In the main experiment, the reliability alpha test was again conducted whereby the result showed that the reliability coefficient (Cronbach's alpha) for the questionnaire set was determined to be highly reliable with α=0.871. As for the validity, the lowest Corrected item-total Correlation value of the items (Q01 – Q07) is 0.544, which is larger than the R table (0.1786), indicating that all of the items are valid.

Descriptive Statistics

Based on the comparison of mean, median and mode values of items Q01-Q07, it is identified that item Q01, Q03, Q04 and Q05 central tendencies are skewed to the right, where the greatest value is mode. Item Q06 and Q07 are skewed to the left, where the largest value is the mean. Item Q02 is symmetrical, where the mean, median and mode values are at the same peak.

Table 4. Descriptive Statistics of The Usability-test

		Q01	Q02	Q03	Q04	Q05	Q06	Q07
N	Valid	121	121	121	121	121	121	121
	Missing	65	65	65	65	65	65	65
Mean		5.43	5.07	5.36	4.81	4.88	4.41	5.02
Median		6	5	5	5	5	4	5
Mode		7	5	7	5	5	4	4
Std. Deviation		1.55	1.60	1.36	1.29	1.39	1.56	1.43
Skewness		-0.98	-0.66	-0.61	-0.39	-0.64	-0.17	-0.49
Std. Error of Skewness		0.22	0.22	0.22	0.22	0.22	0.22	0.22

Therefore, only Q02 has symmetrical data distribution that makes it appropriate to use the mean as the central value. If the distributions were being considered, the median should be used rather than the mean. However, as previously discussed on the piloting test (5.4.1), the use of mean and standard deviation is appropriate, as long it not to be used to make interval/ratio statement.

Results

1. From 121 participants, ninety-one (75.21 %) agreed the platform was easy to use, against 13 (10.74%) participants who disagreed. Seventeen (14%) were undecided. From scale 1 to 7, the score is 5.42 ± 1.55. Significantly increased from the pilot test result (4.47).
2. Eighty-one (66.94%) participants agreed that they were satisfied with the support information while completing the task, as opposed to 17 (14.05%) participants who disagreed. Twenty-three (19.01%) participants were undecided. The mean-rating is 5.07 ± 1.59, increasing from 4.76.
3. Eighty-eight (72.73%) participants agreed that they were satisfied with the amount of time to complete the task, against 7 (5.79%) participants, who disagreed. Twenty-six (21.49%) participants were undecided. The mean-rating is 5.36 ± 1.36, increasing from 5.18.
4. Seventy-three (60.33%) participants agreed that the platform allowed them to express preferences for spaciousness adequately, against 16 (13.22%) participants who disagreed. Thirty-two (26.64%) participants were undecided. The mean-rating is 4.81 ± 1.29, increasing from 4.59.

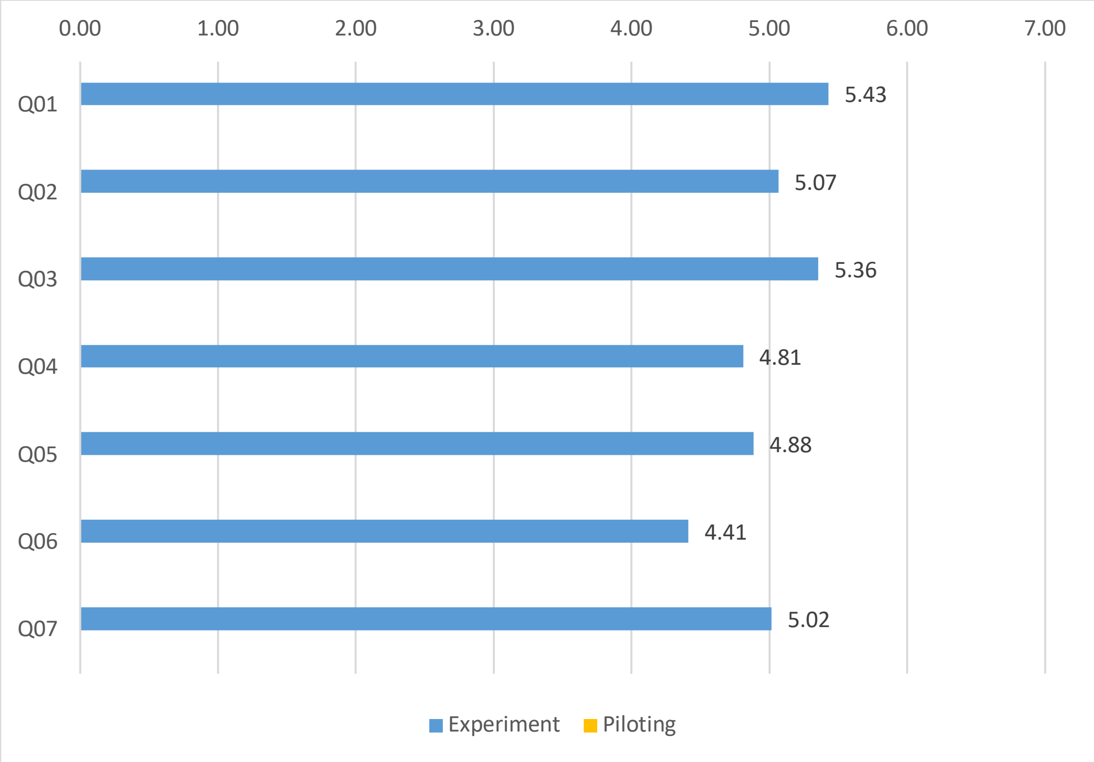


Figure 46. The Usability-test mean score from the pilot test and the first stage. (source: author)

5. Seventy-six (62.81%) participants agreed the platform allowed them to express their preferences for windows and ceiling type adequately, against 16 (13.22%) participants who disagreed. Twenty-nine (23.97%) were undecided. The mean-rating is 4.88 ± 1.39, increasing from 4.53.
6. Fifty-eight (47.93%) participants agreed the platform allowed them to express the Surface Colour adequately, against thirty-one (25.62%) participants who disagreed. Thirty-two (26.45%) participants were undecided. The mean-rating is 4.41 ± 1.56, increasing from 4.29.
7. Seventy-four (61.16%) participants agreed the platform could be used to develop designer awareness of end-user preferences, against 8 (6.61%) participants who disagreed. Thirty-nine (32.23%) participants were undecided. The mean-rating is 5.02 ± 1.43, increasing from 4.88.

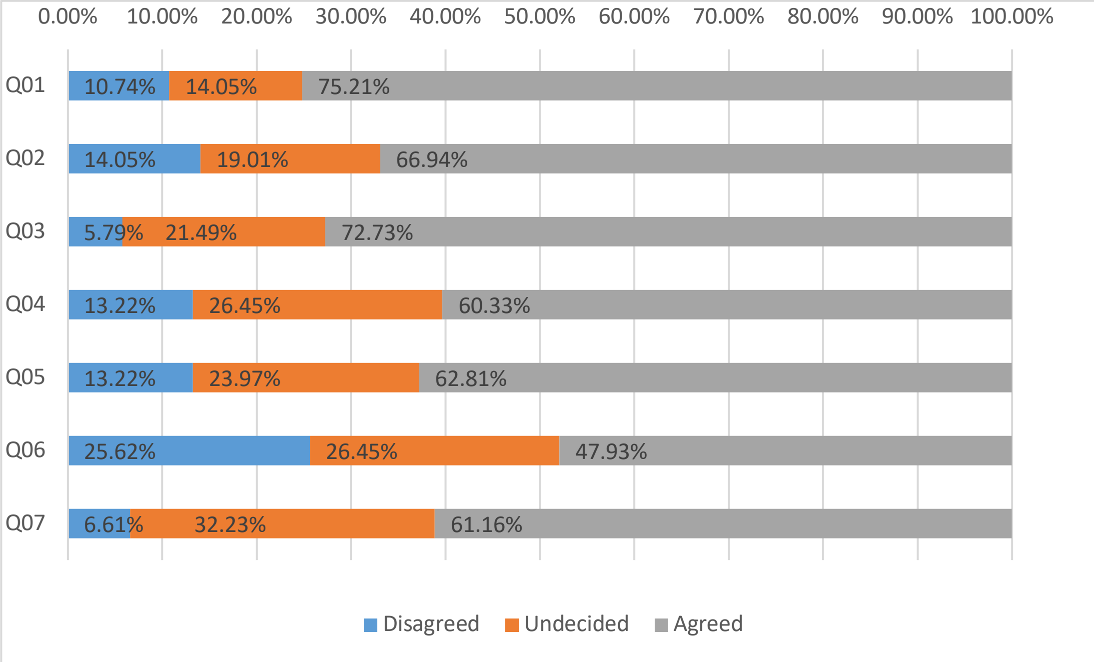


Figure 47. The Usability-test responses distribution (source: author)

Comments and Feedback

The last question required the participants to leave comments and feedback regarding their experience after using the p-VE, where it received 63 written responses. Appendix E.7. listed all of them in their original/unedited form. Since the participants were allowed to respond in their native language, the experiment received the responses in English and Bahasa Indonesia. Navigation issue needed re-interpretation from the original text, since the participants cannot directly express the issue. In the comment field, the words correlated to the design variables that were frequently mentioned are: Colour, color, or *Warna* (in Indonesian's language) 48 times, Window 11 times, Lighting and Ceiling were 8 times, Texture 7 times, furniture 4 times, and the plant was mentioned once. Other selective words frequently mentioned are 'More', which was mentioned 31 times. A few participants reported an inconsistency between the colour on the preview box compared to the applied colour on the surface. The problem occurred when a viewer faces at a shaded surface, to which the colour is rendered darker compared to the real colour. Some volunteers who assisted the participants reported that the problem was solved when the participant was told to look around at different surfaces that have not been affected by the shading effect.

6.4. Confidence Rating

Of all participants, one participant did not respond to the test. Therefore, there were 185 participants in the test. Between them, 41 (22.2%) felt 'Completely confident' during the experiment, 56 (30.3%) 'Very confident' and seventy-two (38.9%) 'Confident'. Only 16 (8.9%) participants felt less confident, ranging from 'Somewhat confident' with 7 (3.8%) participants, 'Not very confident' with 5 (2.7%) participants and 'Not confident at all' from 4 (2.2%) participants. The participants who are 'Completely confident' and 'Very confident' surprisingly accounted for 52.5% of all participants (*Figure 48*).

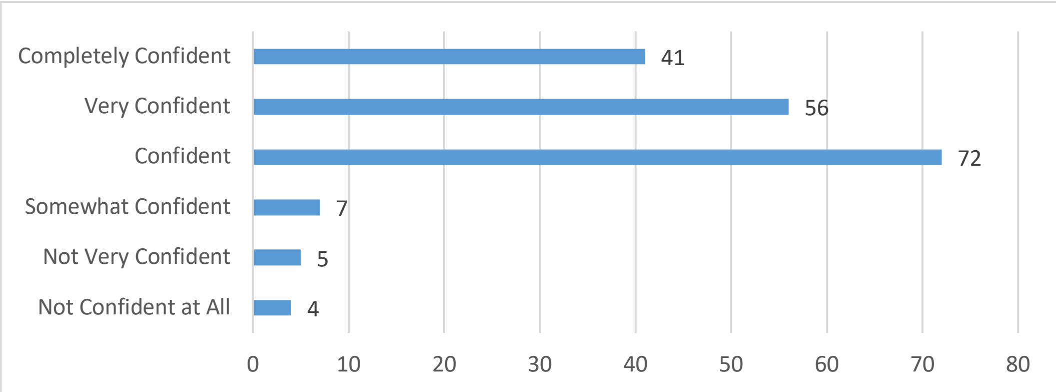


Figure 48. Confidence rating results.
(source: author)

6.5. The Scenes

By the end of the experiments, there were 186 scenes generated by the participants and stored in the cloud database. Each scene is controlled by fourteen parameters that can be recalled whenever required. Anyone who holds the UserID information can access the scene, modify, or just view them. *Figure 49* shows an example of the Scenes.

Based on the experiment results, how should the learning space look? Receiving 186 scenes consists of the user's idea is probably not going to make the decision process any easier for the decision-maker. The chance is to make a selection of the scenes that can be useful. One argument mentioned the Sturgeon's law that "Ninety per cent of everything is crud (crap)", leaving at least 10% as useful. The argument is frequently used by the crowdsourcing supporter to point out the importance of the potential of large-scale participants (Barisano 2013). The larger the participants, the larger the useful alternatives that can be extracted from the crowds.

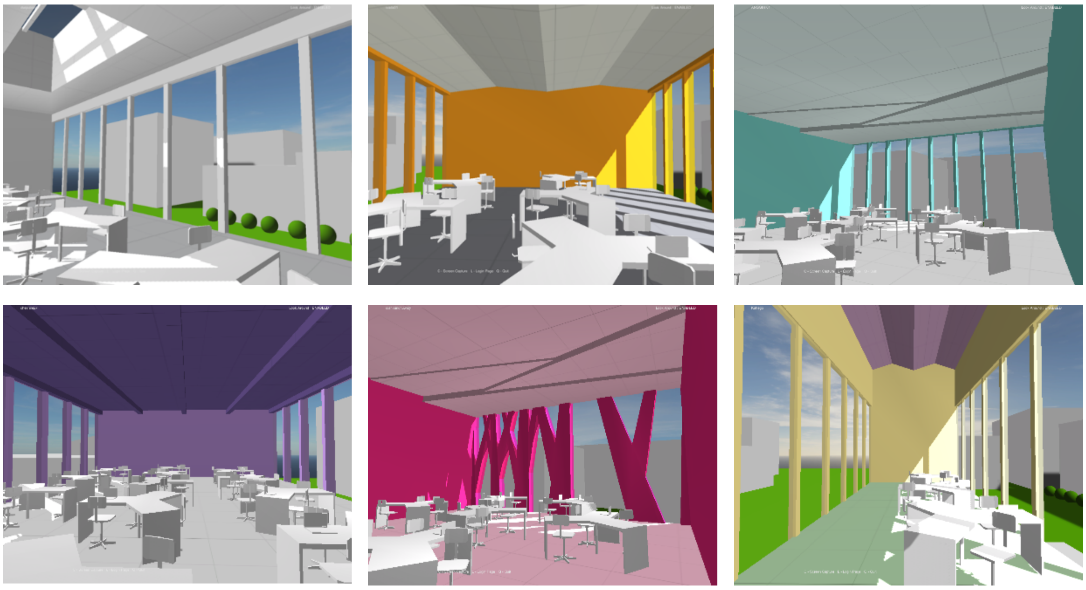


Figure 49. Random Example of the Scenes.
(source: author)

Another approach is to construct a scene using the top-voted components (amalgamated) and use it as a reference. This approach probably too simplifying, since the top-voted components are unlikely to make up more than 50% of the population and there is no guarantee that the components will work together. Let say, in a music contest, the judges have picked the best guitarist, bassist, and drummer. Now the question is, "Will they be able to work together as a band?".

6.6. Preferences Data

Unfortunately, not all of the variables data received are ready for statistical analysis. Some of the variables consist of continuous data (numeric variables that have an infinite number of values between any two values) which need to be grouped to make them quantifiable. In this case, the colour variables that consist of three values (red, green, blue) were converted into categorical (i.e. white, black, etc), while the spaciousness variables were grouped into smaller ranges. To acquire the top-voted components, each group/category was ranked based on the votes received. Since the preferences data is in categorical, Non-parametric Spearman's correlation test was used to investigate the differences between groups. This could be an indication that the design of the preference data in the p-VE need restructuring if the aim of the research is to generate unbiased data that is reliable and valid. The data analysis (Appendix E.2.) showed that the preferences data are widely varied and inconsistent.

Also, the correlation test between the eight variables showed that only Floor Length Z and the Ceiling height have a moderate correlation (0.413), and there are two low correlations found. The rests of them have no correlation at all.

6.6.1. Surface Colours

The surface colour data retrieved from Parse contains three colour combinations: Red, Green, and Blue (RGB). Since there are 48 colours to be reviewed, only the colours that received more than 5% of votes are reported in this section. The complete table can be found in Appendix E.3.

Wall Colour

Among all 186 participants, fourteen (8.14%) of them picked Duck egg as their preferred colour for the wall surface. Blue was preferred by eleven (6.4%) subjects, with white in the third rank, being preferred by ten (5.81%), and with a Sky colour being preferred by nine (5.23%). They are all the colours that collected more than 5% votes. Meanwhile, four colours did not receive any votes, which were Beige, Choc, Coral, and Grey *(Figure 50).*

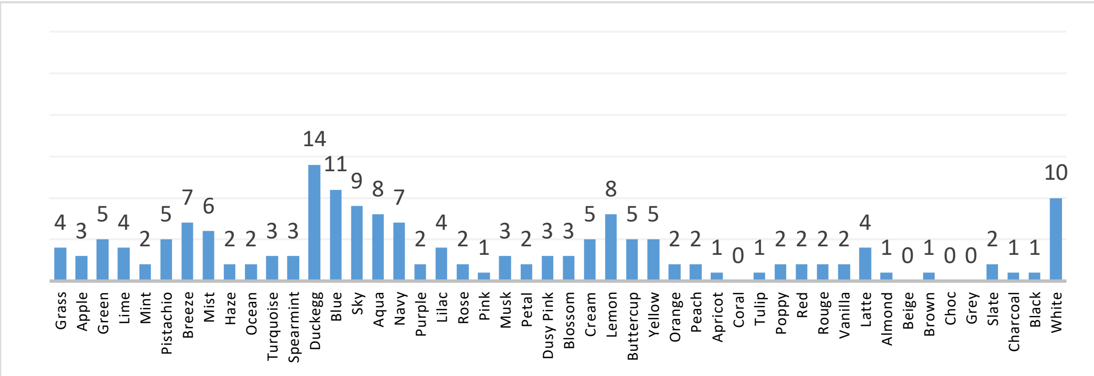


Figure 50. The Wall colours preferences from all the participants.
(source: author)

Ceiling Colour

White was the only colour that was preferred by more than 10% of participants, resulting in twenty-eight (15.64%) votes. The second rank was Blue, which was preferred by fourteen (7.82%) participants, and Breeze was preferred by ten (5.59%) participants. On the least preferred end, only Red did not get any votes for the ceiling colour (*Figure 51).*

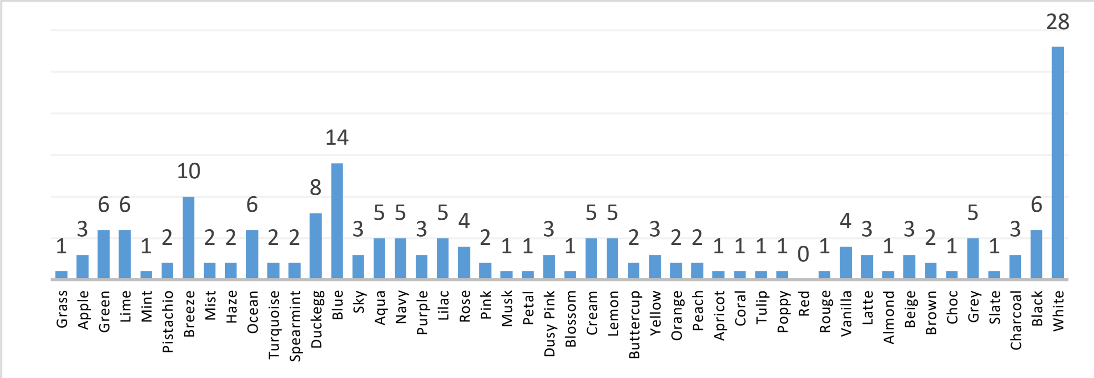


Figure 51. The Ceiling colour preferences from all the participants.
(source: author)

Floor Colour

The results show that two colours received more than 10% of the votes. These colours are White, which received 19 (10.56%) votes, and Charcoal with 18 (10%) votes (*Figure 52*). In the third rank is Black, which was preferred by 12 (6.67%) participants. Six colours were out of favour among the participants. They were Coral, Haze, Lilac, Peach, Pink, and Yellow, which all did not get any votes for the floor colour.

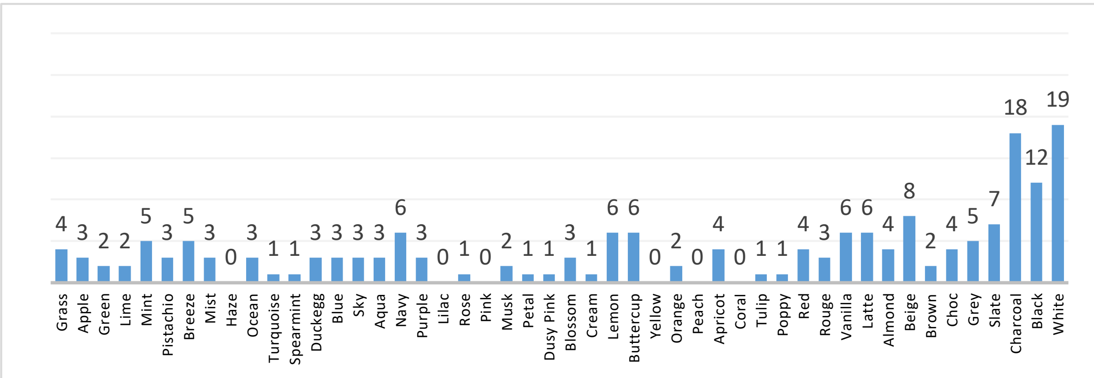


Figure 52. The Floor colour preferences from all the participants.
(source: author)

6.6.2. Spatial Dimensions

Unlike the data for the surface colours and the element style, spatial dimension data is continuous and freely adjustable using a set of sliders. For the analysis purpose, the data was converted into ordinal data by dividing the total floor's range (2 to 16m) into a meter subscale, resulting in fifteen components. The same method also being applied to the ceiling height (2 to 8 m), resulting in six components.

The values retrieved from *Parse* for spatial dimensions represent the scale of the objects and not the actual size of the object. Thus, they must first be converted into metric scale by multiplying them with the original object's size. It also needs to be noted that Unity3-D uses a coordinates system that works differently to the commonly used Cartesian system. The main difference is Z and Y coordinates swap places, by which the Y coordinate goes up rather than on the plane alongside X. Since the Cartesian system is more popular among architects and Designers who will access the results of this study, it is felt necessary to also convert the coordinate system. The complete table can be found in Appendix E.4.

Floor Area

The floor area consists of two variables, which are Length X and Length Z. The first is obtained from ScaleX multiplied by the default object's length, and the second is from ScaleZ multiplied by the default object's length. Since there are 15 classes for each length X and Z, only the top four components will be reported.

The top-voted length for X is 8 – 8.95m was preferred by 36 (19.35%) participants. The second rank is 16m, favoured by 26 (13.98%) participants. The third rank is class 11 – 11.95m with 23 (12.37%) participants. The fourth is 9 – 9.95m, which received 20 (12.75%) votes. Another range outside the highest four that is worth mentioning is the range 10 – 10.95m, which is in the fifth rank, as it was preferred by 19 (10.75%) participants. In the least preferred area, there was only one range that did not receive any votes, which is the 2 – 2.95m range *(Figure 53)*.

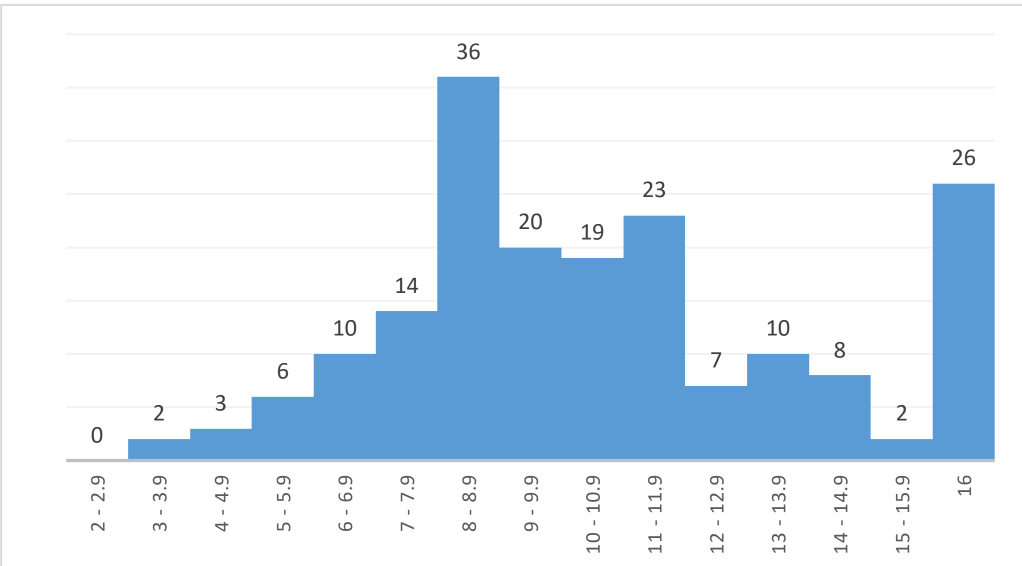


Figure 53. The floor's length X preferences from all the participants.
(source: author)

Similarly, the top-voted length for Z is also the range between 8 – 8.95m, which was favoured by 32 (17.20%) participants, and the second rank is also 16m, that was preferred by 29 (15.59%) participants. In 3rd place is the range 9 – 9.95m, which received 27 (14.52%) votes, and the 4th rank is the range between 10 – 10.95m, which was preferred by 23 (12.37%) participants. The least preferred range was 2 – 2.95m, 3 – 3.95m, and 4 – 4.95m, which received no votes (*Figure 54*).

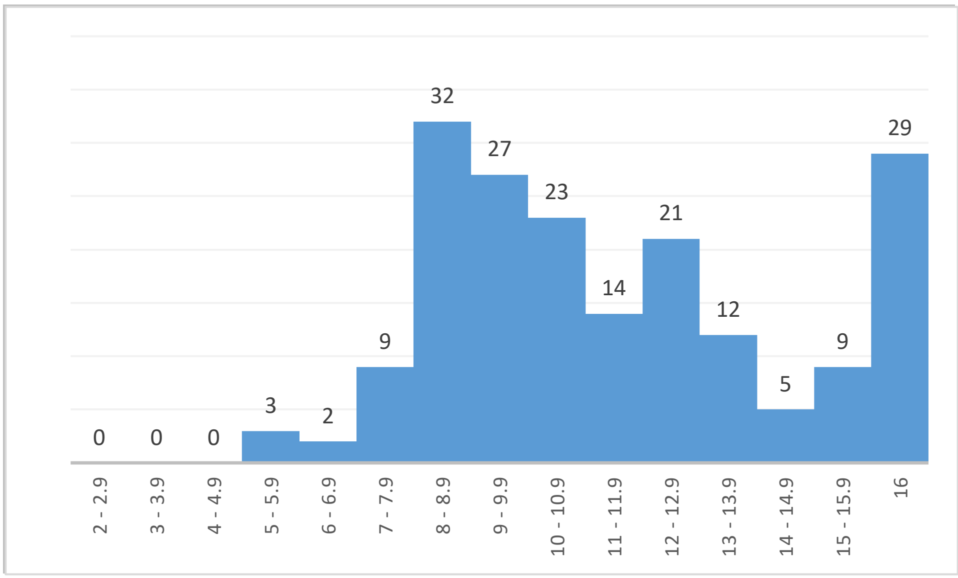


Figure 54. The floor's length Z preferences from all the participants.
(source: author)

Ceiling Height

Unlike the results for the floor area, the ceiling height result forms an inverted U with a high spike in the middle. It means there is a strong preference for ceiling height in this range. There is no sign of strong preferences at the maximum height (8m), which means preferences for a higher ceiling than the current setting is small or unlikely. The top-voted ceiling height of all participants is between 4 – 4.95m, which is preferred by nearly half of the participants with 92 (49.46%) votes. The 2nd rank is the range between 5 – 5.95m that is preferred by 45 (24.19%) participants. The rest of the classes received less than 10% of votes, with the least preferred ceiling height being 2 – 2.95m (*Figure 55*).

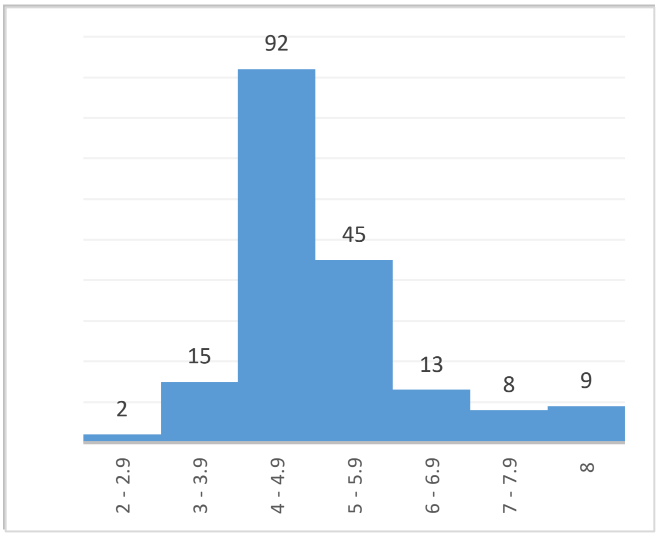


Figure 55. The Ceiling height preferences from all the participants. (source: author)

6.6.3. Elements Style

In the Beta version, Ceiling Style was added along with the existing Windows Style. Each consists of six types/styles labelled as Type01 to Type06. The complete table can be found in Appendix E.5.

Window Style

The top-voted Windows-style was Type03, which collected 67 (36%) votes among the 186 participants (*Figure 56*). The 2nd favourite was Type04, which was voted for by 53 (28.5%) participants. Type05 was in 3rd place with 37 (19.9%) votes. No other window style received more than 10% of votes, with the least preferred being type01, which received 6 (3.2%) votes.

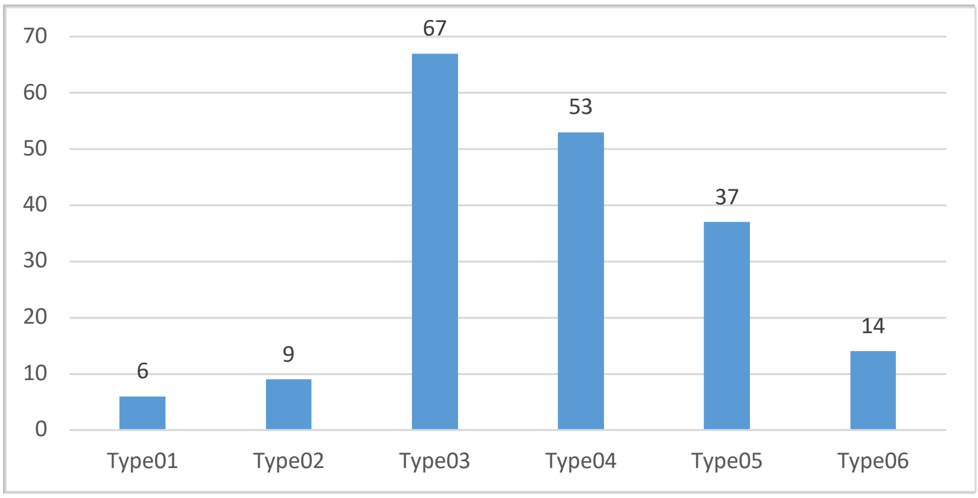


Figure 56. The windows' style preferences from all the participants. (source: author)

Ceiling Style

The top-voted Ceiling Style is Type03, which collected 44 (23.7%) of the total population (*Figure 57*). The 2nd rank was Type05, which features the skylight. It collected votes from 30 (21%) participants. Three other styles also received more than a 10% share. Type04 placed 3rd, and received 34 (18.3%) votes, Type06 received 32 (17.2%) votes, and Type02 received votes from 24 (12.9%) participants. The only one that received less than 10% is Type01, which only collected 13 (7%) votes.

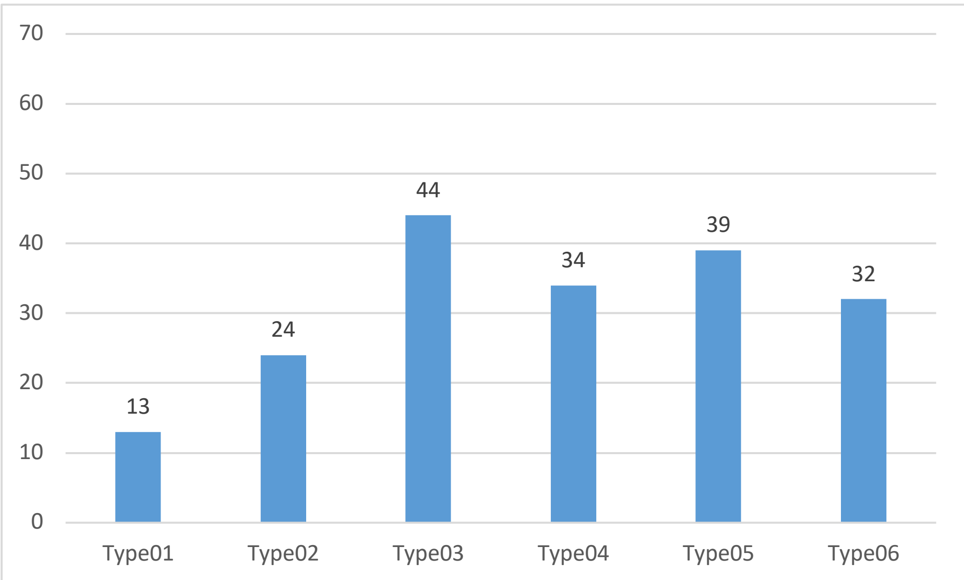


Figure 57. The Ceiling style preferences from all the participants. (source: author)

6.6.4. Visual Preferences Data Document

A document consisted infographics based on visual analytic of the first stage result was prepared for the designers who signed up for the second stage. The data available from April to June 2015 were used to prepare the document, collected from 169 participants. Since the infographics were still under development at the time, the infographics in the document are the earlier version. The document can be found in Appendix G.

6.7. Design and Non-Design Background Comparison

This section investigates how different are the Design and Non-design background preferences. The general argument is that people who have experience in the design field tend to have different preferences compared to those who have little to no experience. In this study, the Non-design group consists of the Students and Others category with a total population of 142 participants. The assumption is the Non-design participants have never previously experience design education. Meanwhile, the Design group consist of the Design students and professional designer categories with a total population of 44 participants.

To find the answer, the visual preference results of the two groups will be compared and correlated. The data collection did not make any effort to control the group's proportion. Thus, some of them are greatly unequal. Of the 186 participants, the Non-design background comprises a total of 142 (76.34%) participants, which then consist of 119 (76.13%) students and 23 (12.37%) Others. Whilst the Design background group comprises a total of 44 (23.66%) participants, with 16 (8.6%) of them Design students (DS), and 28 (15.05%) Professional Designers (D).

6.7.1. Usability-Test

Both groups favoured the usability of the p-VE with all scores averaging above four on the scale 1 to 7. The Non-design mean score of all items (Q01 – Q07) is significantly higher than the design group with 5.05 against 4.88. The three components (Q01 – Q03) mean score of both groups is 5.30 against 5.25, while the function usability (Q04 – Q06) mean score has a significant difference of 4.82 against 4.44. Spearman's test on both groups is strongly correlated with r=0.786.

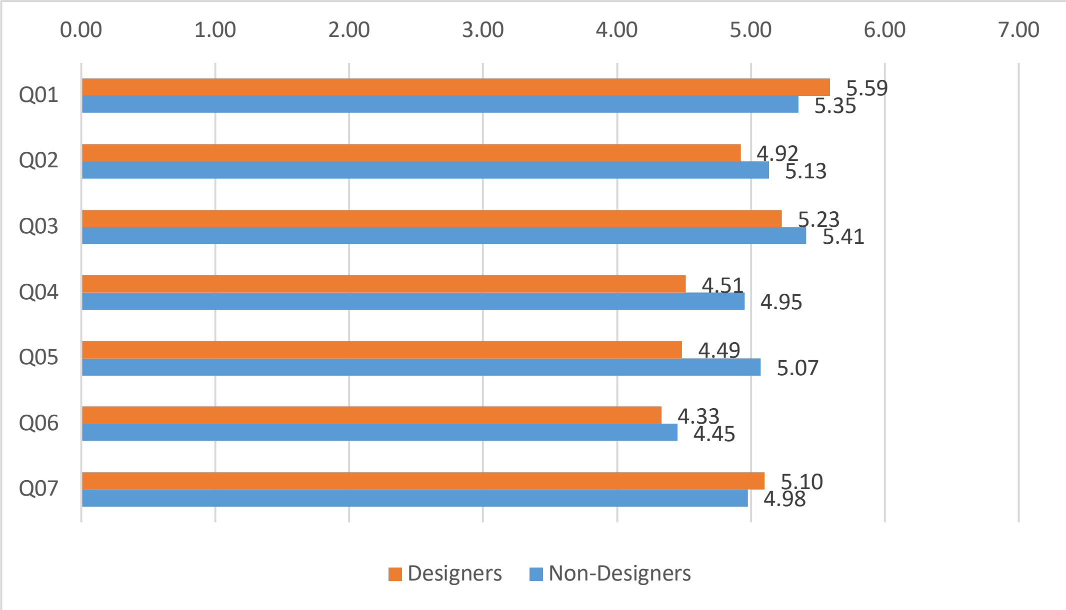


Figure 58. Usability-test result
(source: author)

6.7.2. Preferences

Wall Colour

In the Non-Design group, Duck egg was voted the top-voted colour by 12 (8.33%) participants from the population of 144, followed by White colour, with 9 (6.25%) votes, and Sky with 8 (5.56%) votes *(Figure 59).* In the Design group, Blue was the top-voted colour, which received 4 (9.09%) votes from the 44 population, followed by Cream, Green, and Navy, which received 3 (6.82%) votes each. The Spearman's correlation test shows a weak relationship between the two groups, with r=0.239. The complete table can be found in Appendix F.2. and F.3.

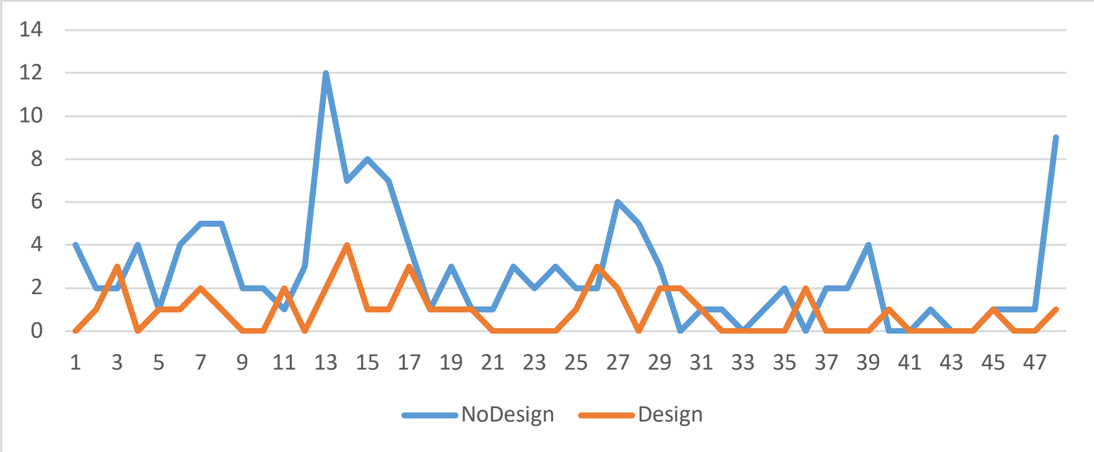


Figure 59. The Correlation of the Wall colour preferences. (source: author)

Ceiling Colour

Both groups voted White as the top-voted ceiling colour. In the Non-Design group, it was voted by 18 (12.50%) participants, followed by Blue with 13 (9.03%) votes (*Figure 60*). In the Design group, White received 10 (22.73%), followed by Duck egg and Lemon, which received 3 (6.82%) votes each. The Spearman's correlation test shows a weak relationship between the two groups, with r=0.357.

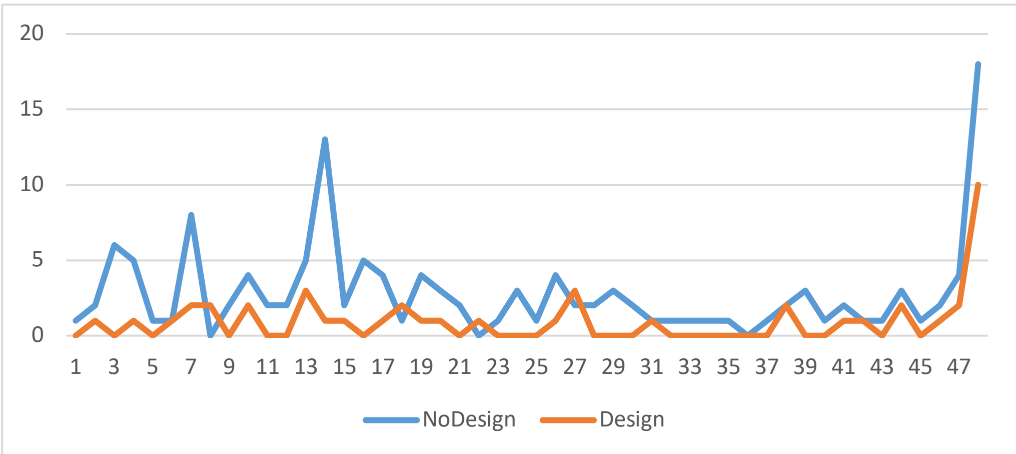


Figure 60. The Correlation of the Ceiling colour preferences (source: author)

Floor Colour

In the Non-Design group, White was voted the top-voted colour by 14 (9.72%) participants, followed by Charcoal with 11 (7.64%) votes (*Figure 61)*. In the Design group, Charcoal was the top-voted colour, receiving 7 (15.91%) votes, followed by Black and White with 5 (11.36%) votes each, Navy with 4 (9.09%) votes, and Choc with 3 (6.82%). The Spearman's test shows a weak correlation between the two groups, with r=0.432

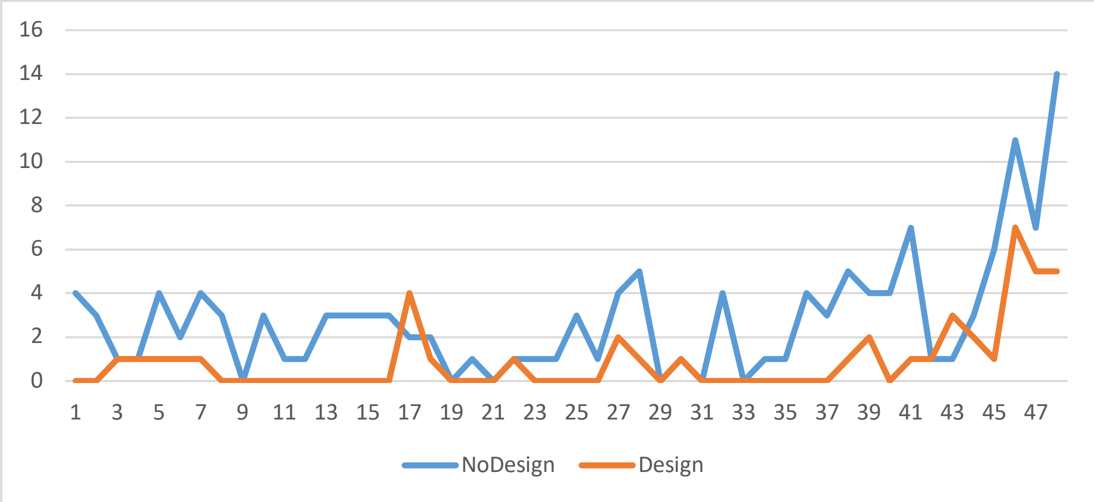


Figure 61. The Correlation of the Floor colour preferences.
(source: author)

Floor area

Both groups voted 8 (or range 8 - 8.95m) as the top-voted length X. In the Non-Design group, 8 – 8.95m was voted by 23 (16.2%) participants from the population of 144, followed by 16m with 21 (14.79%) votes, 11 - 11.95m with 17 (11.97%) votes, and then 10 – 10.95m and 9 – 9.95m which received 15 (10.56%) each. In the Design group, 8 – 8.95m received 13 (29.55%) votes from the population of 44, followed by 11 – 11.95m with 6 (13.64%) votes, then the 16m and 9 – 9.95m range, with 5 (11%) votes each. Spearman's test between the two groups shows a strong correlation with r=0.898.

Note: For the Spatial dimensions comparison, only the length/height that received more than 10% of votes are reported in this section. The complete table can be found in Appendix F.2. and F.3.

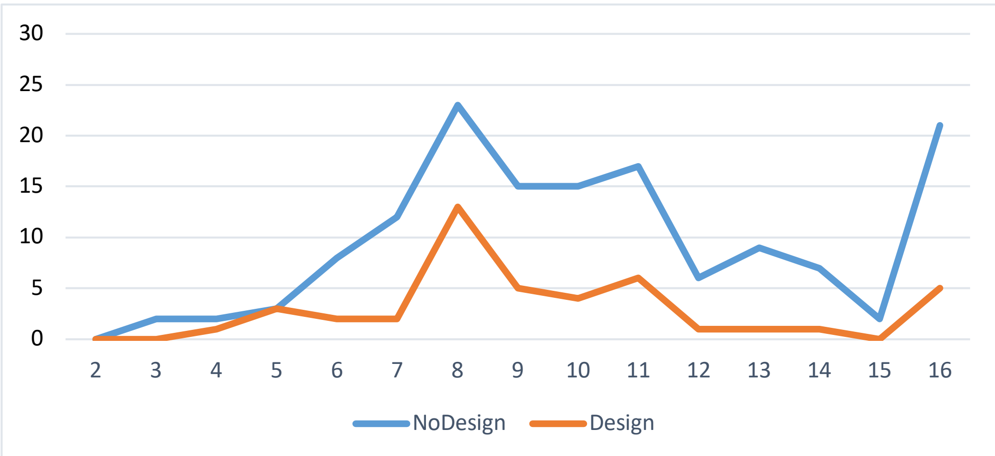


Figure 62. The Correlation of the floor's length X preferences

(source: author)

For length Z, the Non-Design group voted 8 - 8.95m as the top-voted range by 28 (19.72%), followed by 9 - 9.95m with 20 (14.08%) votes, 16m with 19 (13.38%) votes, 12 - 12.95m with 18 (12.68%) votes, and 10-10.95m with 17 (11.97%) votes *(Figure 63)*. In the Design group, 16m was the top-voted length that received 10 (22.73%) votes from the population of 44, followed by 9 – 9.95m with 7 (15.91%) votes, 10 – 10.95m with 6 (13.64%) votes, and 13 – 13.95m with 5 (11.36%) votes. The Spearman's test also shows a strong correlation between the two groups, with r=0.871.

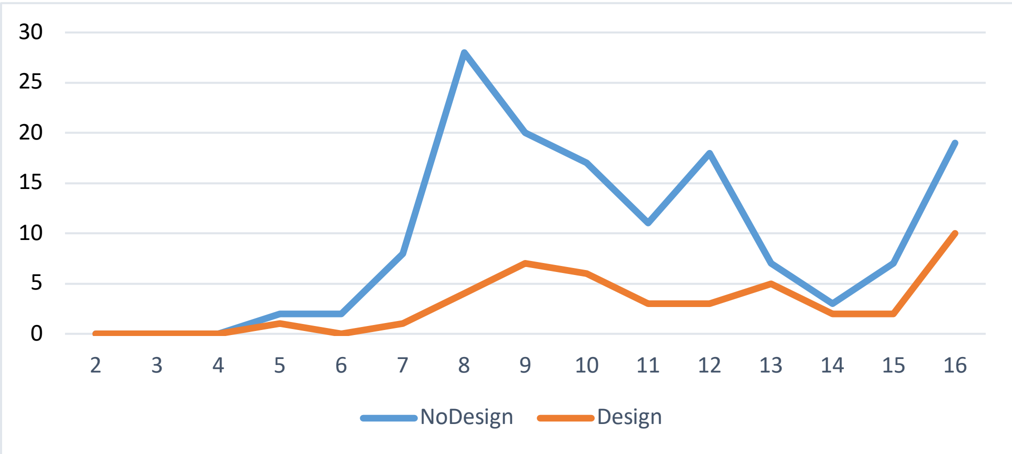


Figure 63. The Correlation of the floor's length Z preferences
(source: author)

Ceiling Height

Both groups also voted 4 (or 4 to 4.95m range) as the top-voted height. In the Non-Design group, it was voted by 69 (48.59%) participants, followed by 5 - 5.95m with 33 (23.24%) votes. In the Design group, the 4 – 4.95m range received 23 (52.27%) votes from the population of 44, followed by 5 - 5.95m with 1 (27.27%) votes and 3 - 3.95m with 5 (11.36%) votes. The Spearman's test also shows a strong correlation between the two groups, with r=0.827.

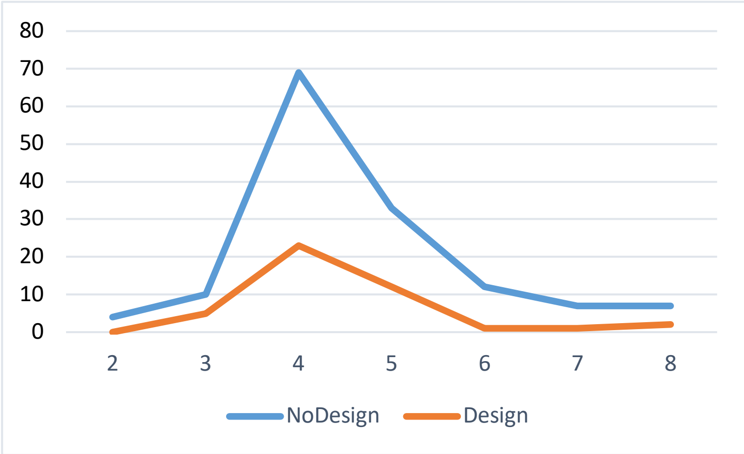


Figure 64. The Correlation of the Ceiling height preferences (source: author)

Window Style

Both groups voted WType03 as the top-voted style. In the Non-design group, it was voted by 48 (33.33%) participants, followed by WType04 with 42 (29.17%) votes, and WType05 with 30 (20.83%) votes *(Figure 65).* In the Design group, WType03 was voted by 19 (43.18%) participants, followed by WType04 with 11 (25%) votes, and WType05 with 7 (15.91%) votes. The Spearman's test also shows a strong correlation between the two groups, with r=0.899.

Note:

For the Window style comparison, only the first three ranks are reported in this section. The complete table can be found in Appendix F.2. and F.3.

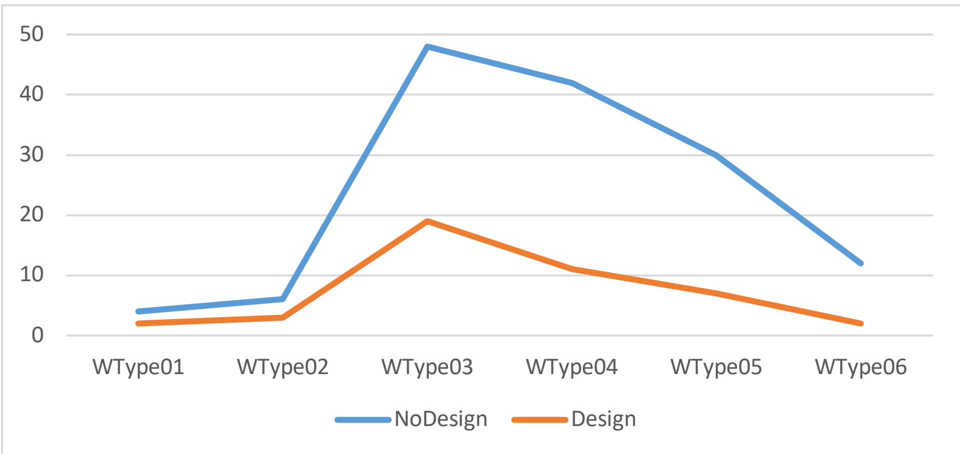


Figure 65. The Correlation of the Window style preferences (source: author)

Ceiling Style

In the Non-design group, CType03 was voted the top-voted style by 36 (25%) participants, followed by CType04 with 31 (21.53%) votes, and WType05 with 30 (18.75%) votes *(Figure 66).* In the Design group, CType05 was the top-voted style, receiving 9 (20.45%) votes, followed by CType06 with 9 (18.18%) votes, then CType02 and CType03 with 8 (18.18%) votes each. Spearman's test showed no correlation with r=0.029.

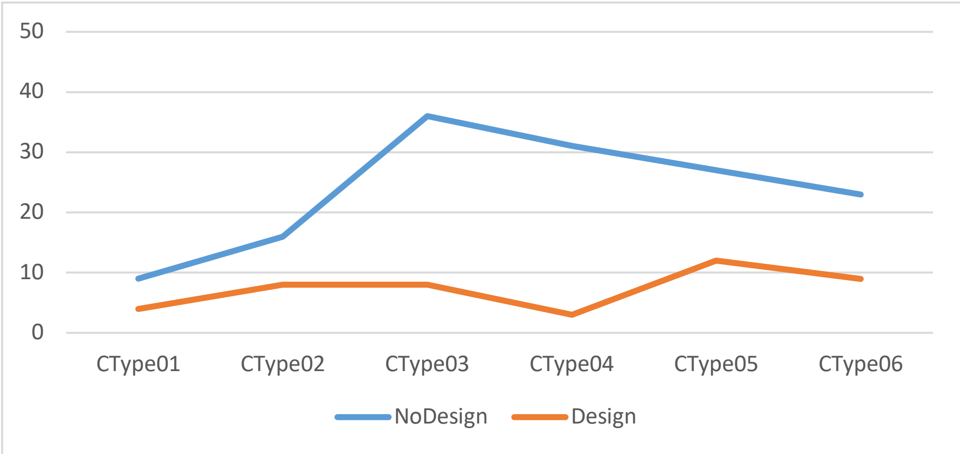


Figure 66. The Correlation of the Ceiling style preferences (source: author)

Summary

Based on the comparison result, both groups are correlated on most of the design variables except the Ceiling style. The table below (Table 5) summarized the comparison result, which also shows both groups share the same top-voted component on four design variables, which is the Window Style (WType03), FloorLength X (8 – 8.9m), Ceiling Height (4 – 4.9m), and Ceiling Colour (White).

Table 5. The Top-voted Components of The Design and Non-Design Participants

		Spearman's Correlation	Top-voted Component	
			Non-Design	Design
Style/Type	Ceiling	0.029	CType03	CType05
	Windows	0.899	WType03	
Length	X	0.898	8 - 8.9m	
	Z	0.871	8 – 8.9m	16m
	Ceiling Height	0.827	4 - 4.9m	
Colour	Ceiling	0.357	White	
	Floor	0.432	White	Charcoal
	Wall	0.239	Duck egg	Blue

The weakest relationship is the Ceiling style (r=0.029, no correlation), which also see each of the groups has different top-voted component. Two variables have weak correlation, which is the Ceiling Colour (r=0.357) and the Wall colour (r=0.239). While the Floor colour has a moderate correlation (r=0.432). Four variables have strong/perfect correlation (Windows Style, Length X, Length Z, and Ceiling Height) and share the same top-voted component between the group, except the FloorLength Z. The complete Spearman's test can be found in Appendix F.3

Spearman's test was used to assess the correlation between the Design and Non-design preferences on all eight design variables consisted of 193 components. The correlation coefficient criterion between variables is ranged from 0 to ±1, with +1 indicates a perfect correlation. Based on the results from SPSS, both groups coefficient is highly correlated with r=0.614.

Table 6. The Correlation test between the Design and Non-Design

			Non-Design	Design
Spearman's rho	Non-Design	Correlation Coefficient	1.000	.614**
		Sig. (2-tailed)	.	.000
		N	193	193
	Design	Correlation Coefficient	.614**	1.000
		Sig. (2-tailed)	.000	.
		N	193	193

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

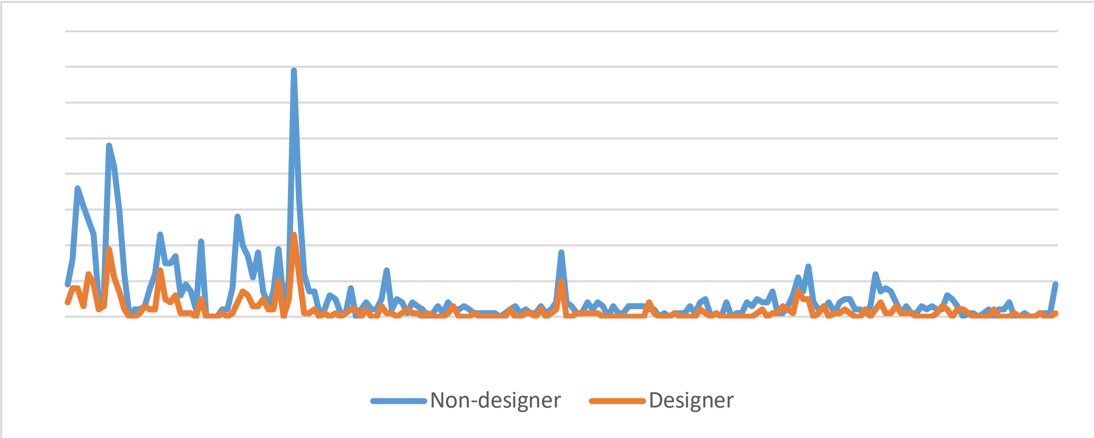


Figure 67. The Design and Non-Design Correlation
(source: author)

6.8. Comparison Based on Gender and Location

6.8.1. Gender

Eighty-two (44.3 %) participants are female, while the male participants numbered 103 (55.7 %). Based on the Spearman's test result using all design variables (N=193), the male and female participants are moderately correlated with r=0.571. Table 7 below summarized the comparison result, which shows both groups shared the same top-voted component on five design variables, which is the Ceiling Type (CType03), FloorLengthX (8-8.9m), Ceiling Height (4 – 4.9m), Ceiling Colour (White), and Floor Colour (White).

Table 7. Top-voted component based on Gender

		Female	Male
Style/Type	Ceiling	CType03	
	Windows	WType04	WType03
Length	X	8 - 8.9	
	Z	8 - 8.9m	16m
	Ceiling Height	4 - 4.9m	
Colour	Ceiling	White	
	Floor	White	
	Wall	Duck egg	Mist

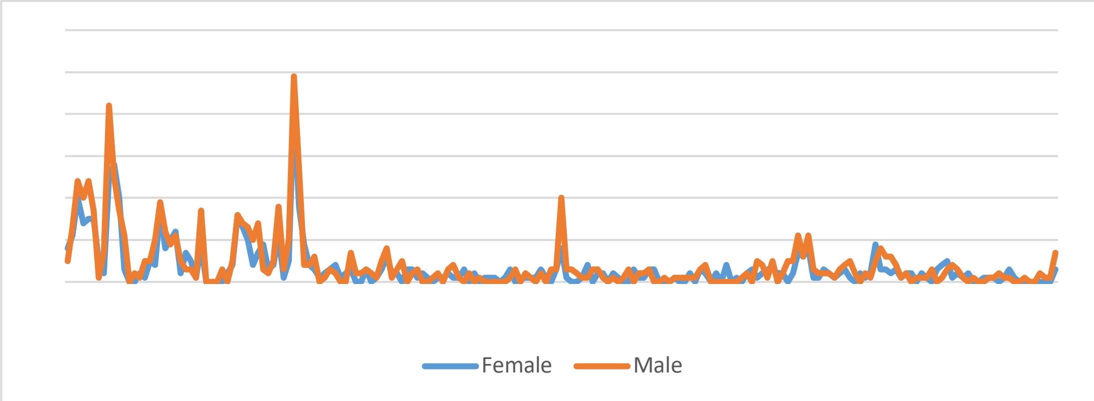


Figure 68. Gender-based correlation
(source: author)

6.8.2. Location

From all the participants, 135 participants (72.6%) located in Indonesia, followed by the United Kingdom with 36 participants, (19.4%), Japan 11 participants (5.91%), two from Thailand (1.08%), one participant from Australia (0.54%), and one participant did not specify the location. Since there are only a few participants from Thailand and Australia, only Indonesia, the UK, and Japan are included in this comparison.

The Spearman's test was used to correlate the participants' preferences from the three locations using all the eight design variables consists of a total of 193 components. The result showed that the participants from Indonesia are moderately correlated to the UK (r=0.570) but weakly correlated to Japan (r=0.394). While the UK and Japan have a moderate correlation with r=0.400. All three locations (Indonesia, the UK, Japan) shared the same top-voted component on the Ceiling Height (4 – 4.9m) and the Ceiling Colour (White). Indonesia and Japan shared the same top-voted components on both floor-length X and Z (8 -8.9m), while the UK and Japan shared the Windows-style (WType03).

Table 8. Location-based top-voted components

		IND (135)	UK (36)	JPN (11)
Style/Type	Ceiling	CType03	CType05	CType01
	Windows	WType04	WType03	
Length	X	8 – 8.9m	16m	8 – 8.9m
	Z	9 – 9.9m	16m	8 – 8.9m
	Ceiling Height	4 – 4.9m		
Colour	Ceiling	White		
	Floor	White	Charcoal	Vanilla, Latte
	Wall	White	Breeze, Duck egg	(Inconclusive)

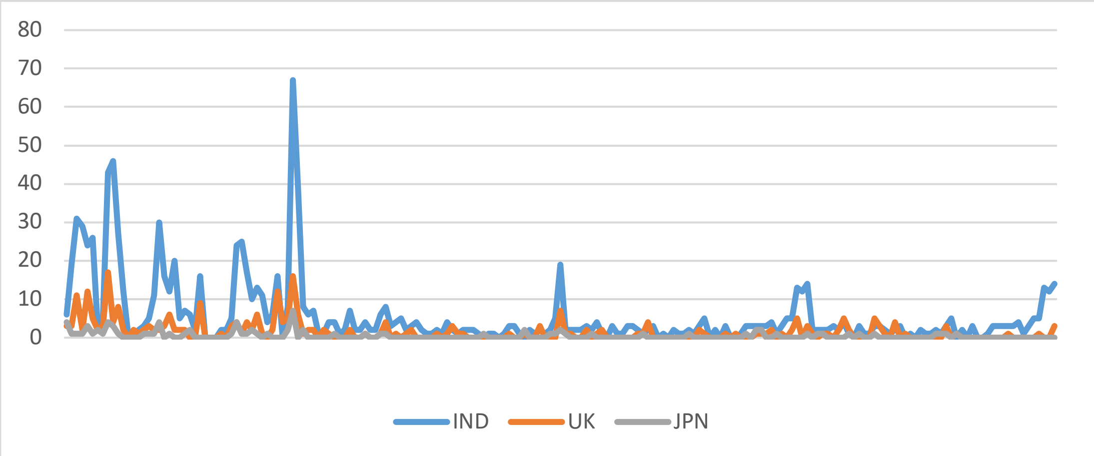


Figure 69. Location-based correlation
(source: author)

Chapter 07
The Second-Stage Results

7.1. Data Gathering

The second stage carried out the data collection from October to December 2015. The busiest traffic was during the 2nd week from 9-16th November 2015 (Figure 70). Like the previous experiment, both data were then downloaded as JSON format and converted into a Spreadsheet format for analysing purposes. As the data from the Preferences Class also consists of other participants from the previous experiment, it needs to get manually separated within a spreadsheet and leave only the participants for the second stage.

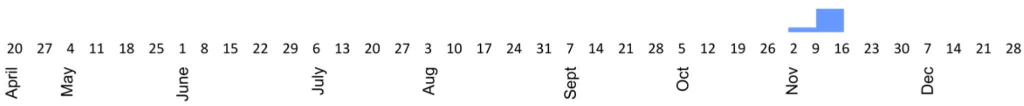


Figure 70. Data traffic for the second stage experiment.
(source: author)

7.2. The Participants

Eighteen designers responded to the invitation by completing both stages. Based on the locations, fourteen (77.78%) participants are from Indonesia and three (16.67%) from the United Kingdom, while one (5.56%) participant decided not to reveal the location. Based on their occupation, two (11.11%) are architects, and fourteen (77.78%) are Interior designers who experienced in the design education or the professional field. Two (11.11%) other participants are post-graduate design students who also have previous work experience. All of them completed the First stage on separate occasions. Based on login date data, four (22.22%) were from the previous session, and fourteen (77.78%) are new recruits that joined-up on the second session.

There were also reports regarding the participants being unable to install the web-player on a certain web-browser. The issue has been reported during the first session. There was also an issue with a participant who did not use the Beta 0.2 version for the second stage but used the Beta 0.1 version instead. Consequently, the designer's data for the second stage is unavailable, and cannot be used for the comparison purpose.

7.3. Questionnaire Analysis

The following section will show the participants' responses to the statements at the end of the p-VE on the Second stage. As previously explained, the scale is from strongly disagree, to Neutral, and Strongly Agree. The questionnaire results can be seen in *Figure 71.*

Reliability and Validity

Using the responses received from the 18 designers, the reliability alpha test was conducted for the second stage, whereby the result showed that the reliability coefficient (Cronbach's alpha) for the questionnaire set was determined to be very highly reliable with α=0.838 (Appendix H.1.). The item with the lowest Corrected item-total Correlation value is Q09 (0.232), although it still valid and be categorised as good discriminating. If comparing each item to the R table for 18 subjects, it can be seen that the value of the item Q01, Q02, Q03, Q05, Q06, and Q08 are larger than 0.4683.

Descriptive Statistics

Based on the comparison of mean, median and mode values of items Q01-Q09, it is identified that item Q01, Q04, Q05 and Q06 central tendencies are skewed to the right, where the greatest value is mode. Item Q02 and Q07 are skewed to the left, where the largest value is the mean. None of the Items is symmetrical, where the mean, median and mode values are at the same peak, the closest item is Q07.

Table 9 Descriptive Statistics of the 2nd Stage Questionnaire

		Q01	Q02	Q03	Q04	Q05	Q06	Q07	Q08	Q09
N	Valid	18	18	18	18	18	18	18	18	18
	Missing	0	0	0	0	0	0	0	0	0
Mean		6.06	5.33	5.17	5.61	5.72	5.56	5.11	5.28	5
Median		7	5	5.5	6	6	6	5	5	4.5
Mode		7	5	5[a]	7	7	6	5	4	4[a]
Std. Deviation		1.59	1.33	1.72	1.69	1.23	1.38	1.68	1.27	1.81
Variance		2.53	1.77	2.97	2.84	1.51	1.91	2.81	1.62	3.29
Skewness		-2.18	-0.70	-1.14	-1.46	-0.26	-1.03	-1.04	-0.01	-0.40
Std. Error of Skewness		0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54

a. Multiple modes exist. The smallest value is shown

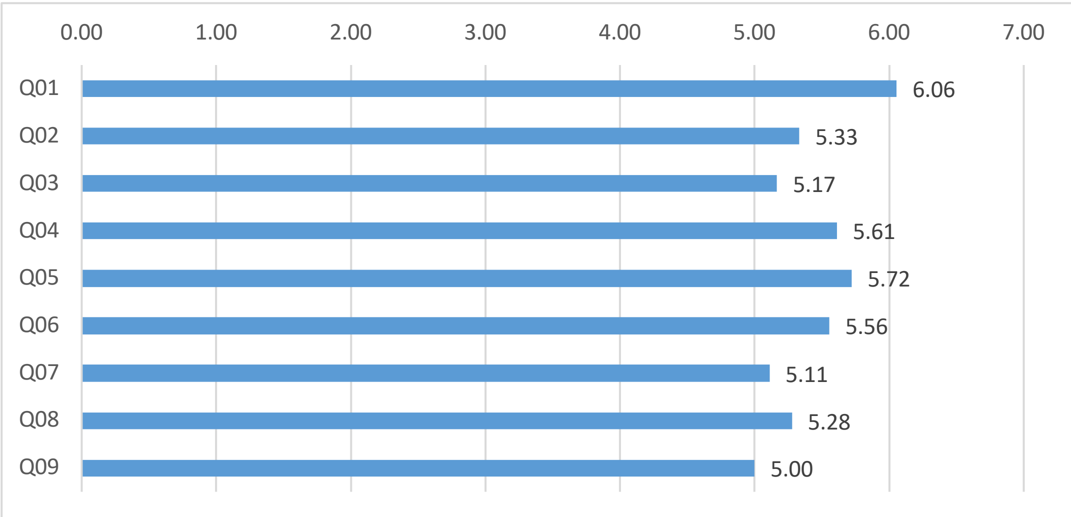


Figure 71. Questionnaire results.
(source: author)

1. From the eighteen participants, sixteen (88.89%) agreed that the PDF document was easy to understand, of which ten strongly agreed, against 1 (5.56%) participant who disagreed, and 1 (5.56%) participant was undecided/neutral. The mean-rating for this statement is 6.06.
2. Fourteen (77.78%) participants agreed that the colour preferences data influenced their decision on the second stage, against 1 (5.56%) participants who disagreed. Three (16.67%) participants were undecided. The mean-rating is 5.33.
3. Fourteen (77.78%) participants agreed that the spatial dimension preferences data was influential on their decision on the second-stage, against 3 (16.67%) participants who disagree, and 1 (5.56%) remained undecided. The mean-rating is 5.17.

4. Fourteen (77.78%) participants agreed that the Windows and Ceiling preferences data were influential for their decision on the second stage, against 2 (11.11%) participants who disagreed. Two (11.11%) participant was undecided. The score is 5.61.

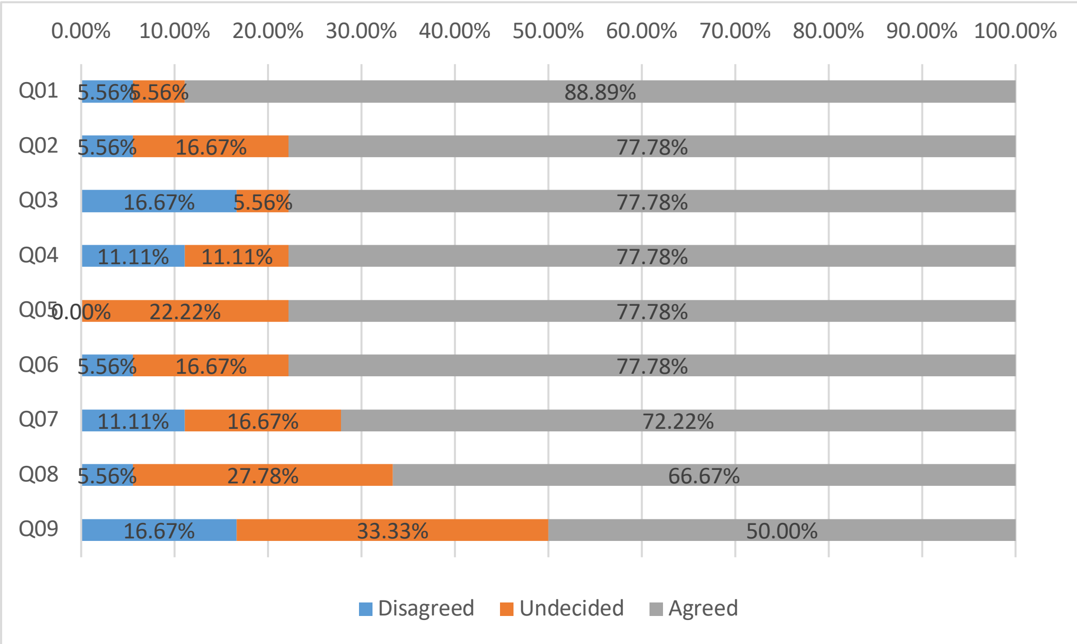


Figure 72. Questionnaire results.
(source: author)

5. Fourteen (77.78%) participants agreed that the Visual Preferences data helped them to understand the user's characteristics. None disagreed. Four (22.22%) participant remained undecided. The score is 5.72.
6. Fourteen (77.78%) participants agreed that the data helped the designers to understand the design direction, against 1 (5.56%) participant who disagreed. Three (16.67%) were neutral. The score is 5.56.
7. Thirteen (72.22%) designers agreed that the visual preferences data put restrictions on design creativity, against 2 (11.11%) participants who disagreed. Three (16.67%) participants were undecided. The score is 5.11.
8. Twelve (66.67%) designers agreed that they would use the visual preferences data as guidance for the design development process, against 1 (5.56%) participants who disagreed. Five (27.78%) remained undecided. The score is 5.28.
9. In response to the ninth statement, nine (50%) designers 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. The score for this statement is 5.

The 10th item of the questionnaire is a fill-in statement for the participants to leave written feedback. Their responses on whether there are other things they can learn from the visual preferences data. Few comments left by the subjects mentioned: “proportion of space”, “colour harmony” and “good communication between designers and clients.”

7.4. The Designer’s Response Comparison

From the eighteen Scenes created by the designers, each comprises eight variables. They are the wall colour, ceiling colour, floor colour, floor’s length X, floor-length Z, ceiling height, windows style, and ceiling style. Therefore, in total there are 144 variables that need to be compared. An analytic sheet was used that consisted of the graphic charts previously produced for the PDF-document. The results from both stages were then plotted side-by-side on the chart for comparison. If the alteration is made in the second stage in accordance with the participants’ preferences (PDF-document), it is considered as favoured and marked with a green circle. Otherwise, it is considered as unfavoured and marked with a red circle. If there were no changes made by the designers, it is considered Neutral, or Unchanged, and marked with a grey circle.

The following figures show the Scenes created by the designers on both stages. In the right column is the designer’s self-assessment results on the influence-level of the participant’s preferences to the designer decision in the second stage. The completed analysis sheets can be found in Appendix H.

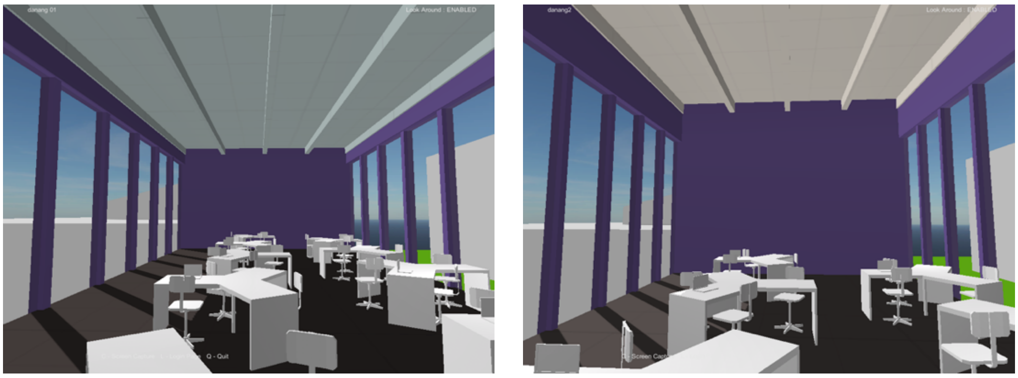


Figure 73. The learning space scene by the Designers 01 in the first stage (left), and the second stage (right).
(source: author)

Designer 01

The designer made three changes in the second stage, one was Favoured, and two were Unfavoured alterations *(Figure 73).* The favoured was the ceiling colour, that changed from Mist to Cream, while the Unfavoured changes were the floor's length X from 8 to 6.88m, and the floor's length Z from 16 to 10.32m, that made the floor's area smaller. Overall the designer was unfavoured of the preferences of the participants.

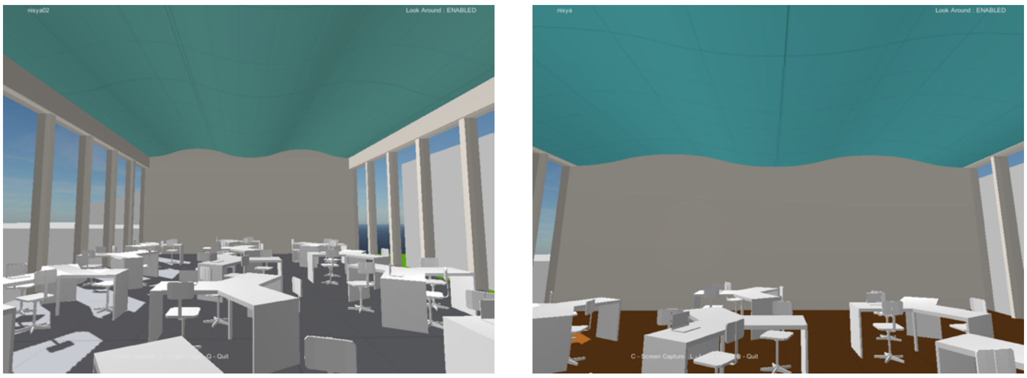


Figure 74. The learning space scene by the Designers 02 in the first stage (left), and the second stage (right).
(source: author)

Designer 02

The designer made five changes, in which two were favoured and three were Unfavoured *(Figure 74).* The favoured alterations were the floor colour from Choc to Charcoal, and the floor-length Z from 9.76 to 16m. The Unfavoured was the wall colour from Breeze to

Cream, the ceiling colour from Ocean to Turquoise, and the floor-length X from 11.76 to 9.92m. Overall the designer was unfavoured of the preferences of the participants.

Figure 75. The learning space scene by the Designers 03 in the first stage (left), and the second stage (right).
(source: author)

<u>The designer 03</u> altered all eight parameters on the second stage. The favoured were the walls colour from Orange to White, the floor colour from Black to White, the floor-length Z from 10.08 to 8m, and the ceiling style from CType05 to CType03 *(Figure 75).* The Unfavoured were the ceiling colour from White to Ocean, the floor-length X from 11.04 to 13.12m, the Ceiling' height from 4.48 to 5m, and the Windows' style from 4 to 6. Therefore, since the designer shared the favoured and Unfavoured equally, the designer is regarded as Neutral.

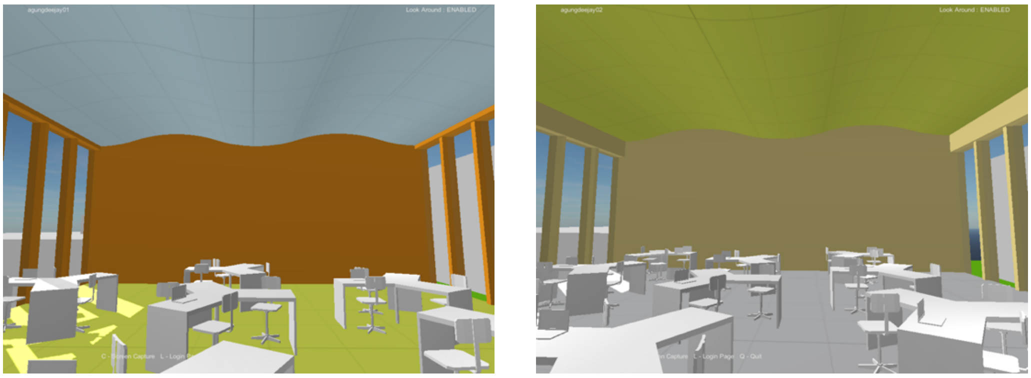


Figure 76. The learning space scene by the Designers 04 in the first stage (left), and the second stage (right).
(source: author)

Designer 04

The designer made five changes in the second stage, in which three were favoured and two were Unfavoured *(Figure 76).* The favoured were the Wall colour from Orange to Lemon, the ceiling colour from Beige to Lime, and the Floor colour from Lime to Grey. The unfavoured alterations were the Floor Length X was changed from 10 to 12m, and the floor-length Z from 10.32 to 11.84m. The rest were left unchanged. Overall, the designer was favoured of the preferences of the participants.

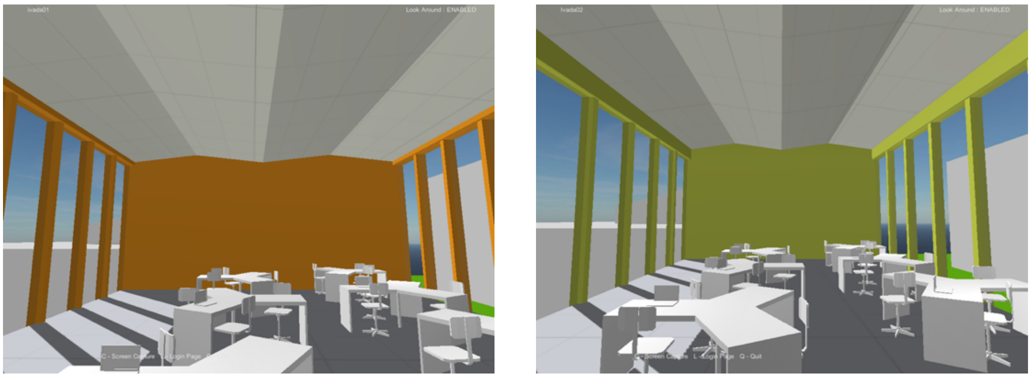


Figure 77. The learning space scene by the Designers 05 in the first stage (left), and the second stage (right).
(Source: author)

Designer 05

The designer made three changes in the second stage with one favoured and three unfavoured alterations *(Figure 77).* The favoured was the wall colour from Orange to Lime, while the rest were kept unchanged. The Unfavoured was the floor-length X from 8.96 to 7.68m, and Floor Length Z from 11.12 to 13.76m. Overall, the designer was unfavoured of the participant's preferences.

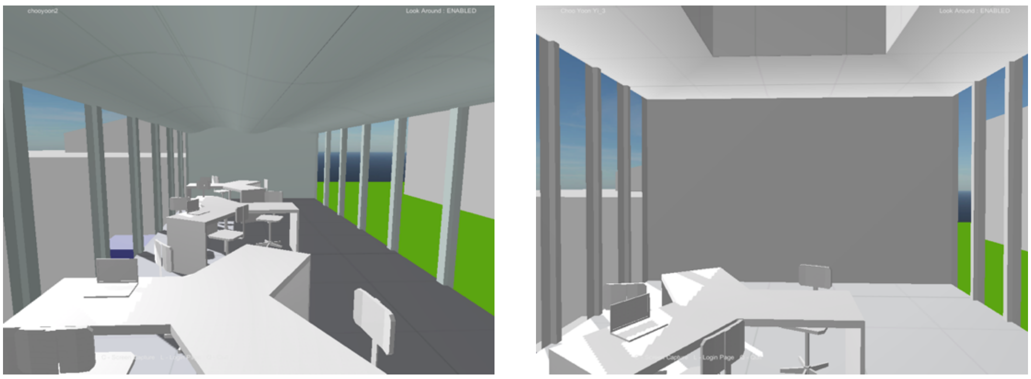


Figure 78. The learning space scene by the Designers 06 in the first stage (left), And the second stage (right).
(Source: author)

Designer 06

The designer made six alterations in the second stage, in which four were favoured and three Unfavoured (*Figure 78).* The favoured alterations were the wall colour from Breeze to

White, the ceiling colour from Breeze to White, the floor's length X from 3.92 to 4.96m, and the ceiling height from 2 to 3m. The Unfavoured were the floor colour from Charcoal to Grey, the floor's length Z from 10.56 to 5.76m, and the ceiling style from Ctype03 to Ctype05. Overall the designer was favoured of the preferences of the participants.

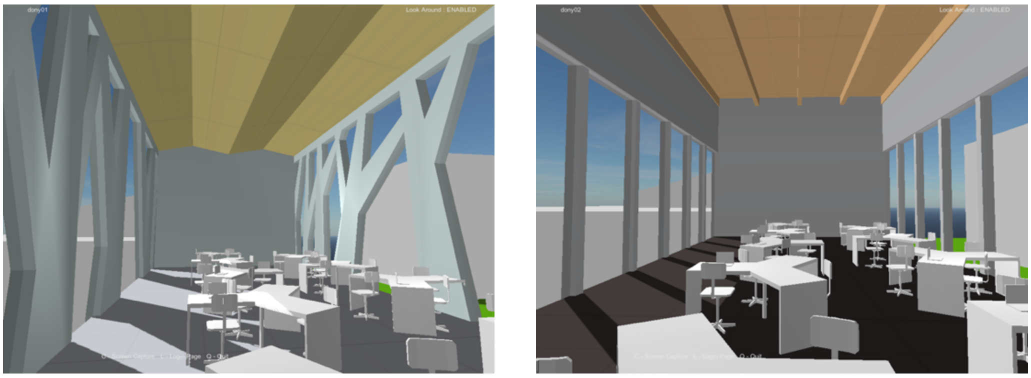


Figure 79. The learning space scene by the Designers 07 in the first stage (left), And the second stage (right). (Source: author)

Designer 07

The designer made seven changes in the second stage, in which three were favoured and four unfavoured alterations (*Figure 79).* The favoured were the floor's X length from 6.88 to 8.08m, the window's style from WType03 to WType04, and the ceiling style from CType02 to CType04. The Unfavoured alterations were the Wall colour from Mist to Grey, the ceiling colour from Lemon to Apricot, the floor's' colour from Charcoal to Black, and the ceiling height from 5.32 to 6.25m. Overall the designer was unfavoured of the preferences of the participants.

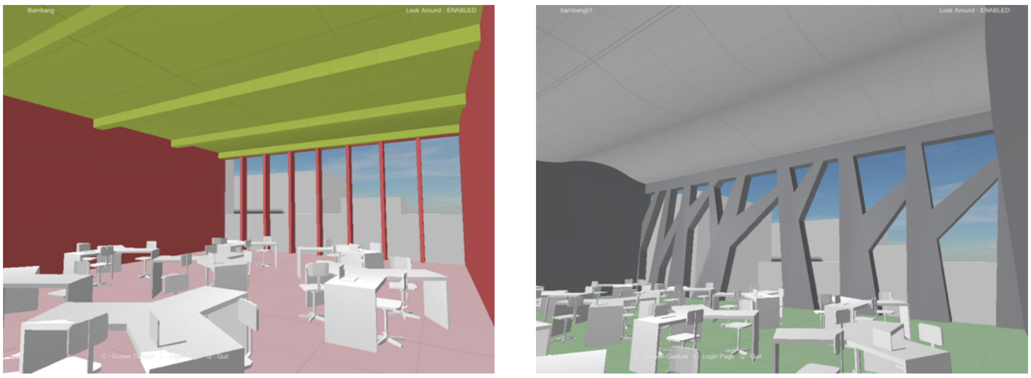
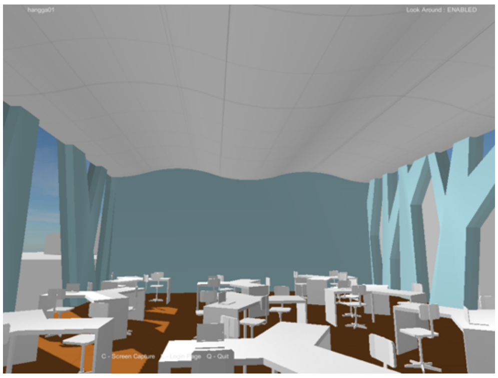


Figure 80. The learning space scene by the Designers 08 in the first stage (left), And the second stage (right). (Source: author)

Designer 08

The designer also made seven changes in the second stage, in which five were favoured and two unfavoured *(Figure 80).* The favoured were the ceiling colour from 3 to 48, the floor colour from 24 to 5, the floor's X length from 12.32 to 10.48m, the floor's Z length, and the ceiling style from 4 to 2. The Unfavoured was the ceiling height from 4 to 5.52m and the window's style from 3 to 4. Overall, the designer was favoured of the preferences of the participants.



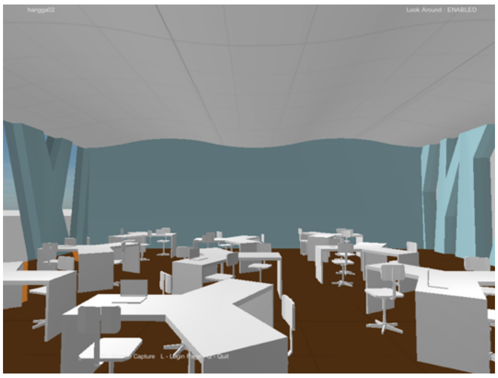


Figure 81. The learning space scene by the Designers 09 in the first stage (left), And the second stage (right).
(Source: author)

Designer 09

The designer made three changes in the second stage, of which one was favoured, and two were unfavoured alterations *(Figure 81).* The favoured alteration was the floor's length Z, that has been changed from 13.36 to 12.96m. The Unfavoured was the floor's length X that has been modified from 10.4 to 13.12m, and the ceiling height from 4.32 to 3.84m. Overall, the designer was unfavoured of the preferences of the participants.

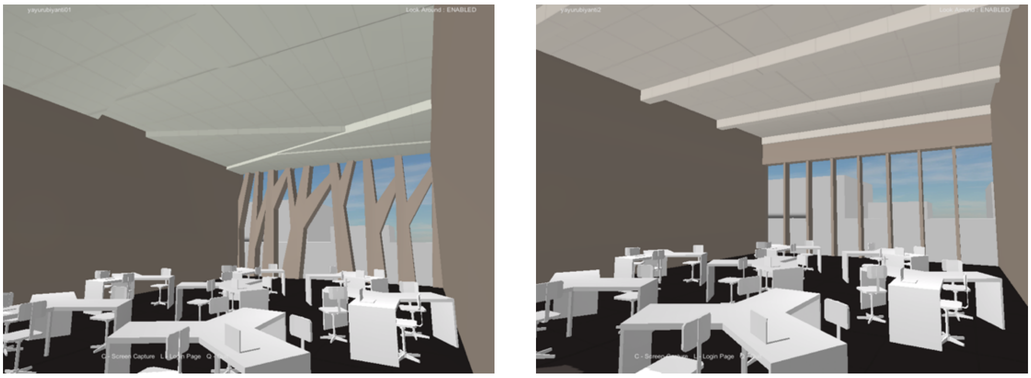


Figure 82. The learning space scene by the Designers 10 in the first stage (left), and the second stage (right). (Source: author)

Designer 10

The designer made five changes in the Second Stage, in which three were favoured and two were unfavoured alterations *(Figure 82).* The favoured were the ceiling colour from Vanilla to Cream, the window's style form WType04 to WType03 and the ceiling style from CType06 to CType04. The Unfavoured was the floor's length Z from 8.4 to 9.28, and the ceiling height from 4.32 to 3.84m. Overall, the designer was favoured of the preferences of the participants.

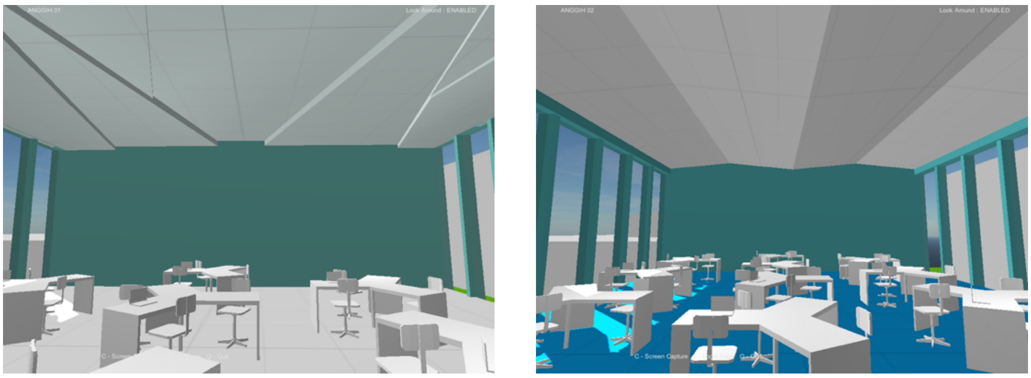


Figure 83. The learning space scene by the Designers 11 in the first stage (left), and the second stage (right). (Source: author)

Designer 11

The designer made six changes, in which one was favoured and five Unfavoured *(Figure 83).* The favoured alteration was the Ceiling colour from Breeze to White. The Unfavoured was the wall colour from Turquoise to Ocean, the floor colour from White to Aqua, the Floor's length X from 11.28 to 10.72m, the Floor's length Z from 10 to 14.16m, and the ceiling style from CType06 to CType02. Overall, the designer was unfavoured of the preferences of the participants.

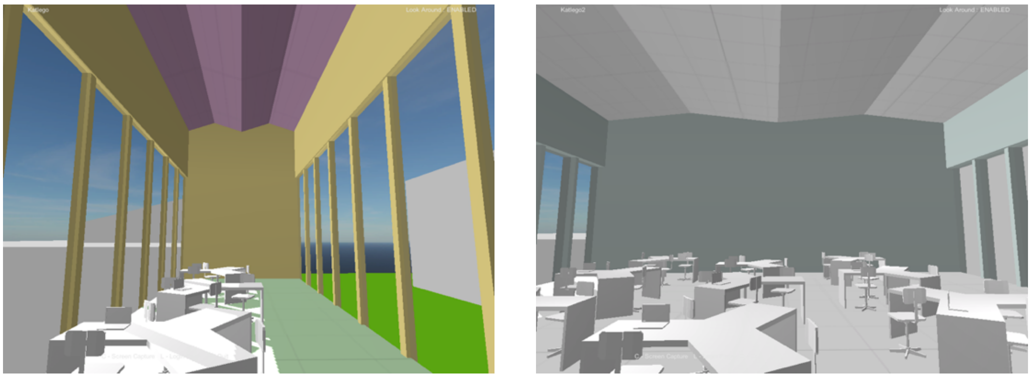


Figure 84. The learning space scene by the Designers 12 in the first stage (left), and the second stage (right). (Source: author)

Designer 12

The designer made four changes, in which three were favoured and one unfavoured alteration *(Figure 84).* The favoured were the ceiling colour from Lilac to White, the floor colour from Mint to White, and the floor colour length X from 4.56 to 13.92m. The unfavoured was the colour of the walls that have been changed from Lemon to Breeze. Overall, the designer was favoured of the preferences of the participants.

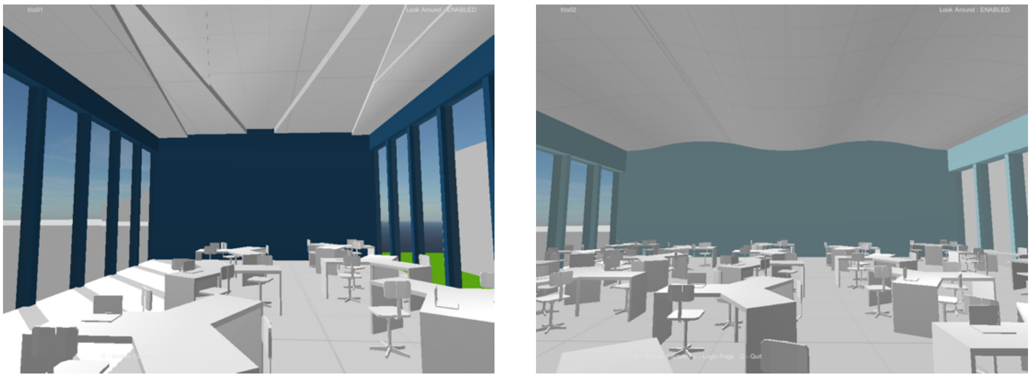


Figure 85. The learning space scene by the Designers 13 in the first stage (left), and the second stage (right). (Source: author)

Designer 13

The designer made four changes, in which two were favoured and two unfavoured alterations *(Figure 85).* The favoured were the wall colour from Navy to Blue and the floor's length Z from 16m to 12.8m. The unfavoured was the colour of the walls that have been changed from Lemon to Breeze. Overall, the designer was favoured of the preferences of the participants.

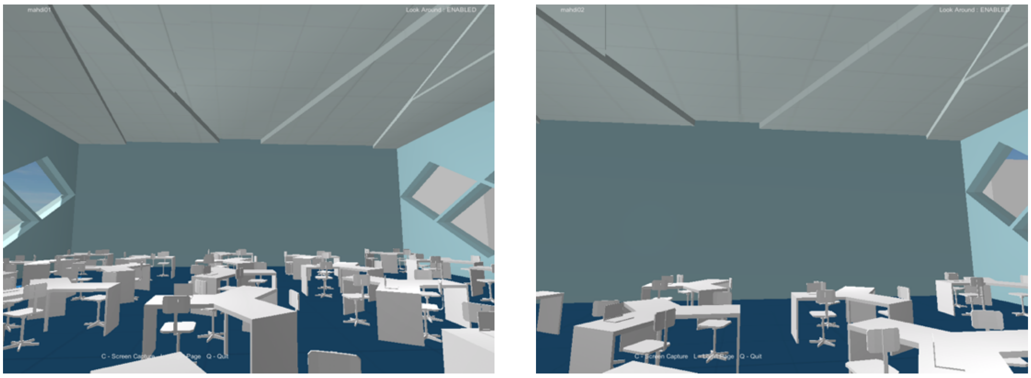


Figure 86. The learning space scene by the Designers 14 in the first stage (left), and the second stage (right).
(Source: author)

Designer 14

The designer made only one change, which is the floor's length Z from 16 to 10.32m. The designer did not change the other variables *(Figure 86).* The designer was favoured of the preferences of the participants overall.

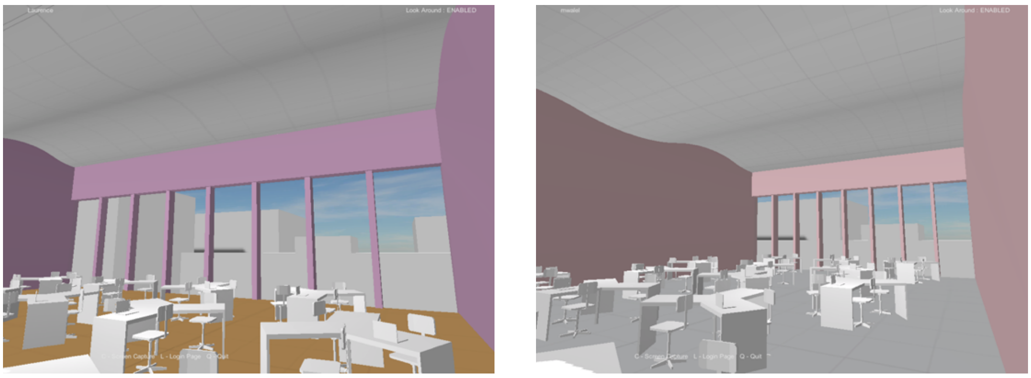


Figure 87. The learning space scene by the Designers 15 in the first stage (left), and the second stage (right).
(Source: author)

Designer 15

The designer made three changes, in which one was favoured, and two unfavoured alterations *(Figure 87).* The favoured was the floor's length X, from 10.8m to 16m, while the Unfavoured was the wall colour from Lilac to Dusty pink and the floor's length Z from 16 to 11.12m. Overall, the designer was unfavoured of the preferences of the participants.

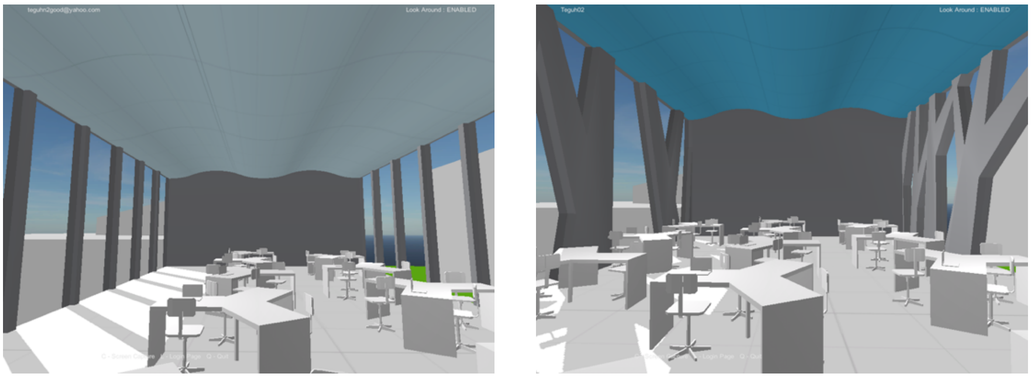


Figure 88. The learning space scene by the Designers 16 in the first stage (left), and the second stage (right).
(Source: author)

Designer 16

The designer made five changes in total, in which three were favoured and two unfavoured alterations *(Figure 88).* The favoured were the colour of the walls from Slate to Cream and the ceiling height from 3.95m to 5m. The Unfavoured was the floor's length X from 8.72m to 9.28m, the floor's length Z from 15.44m to 14.4m, and the window's style from WType03 to WType04. Overall, the designer was unfavoured of the preferences of the participants.

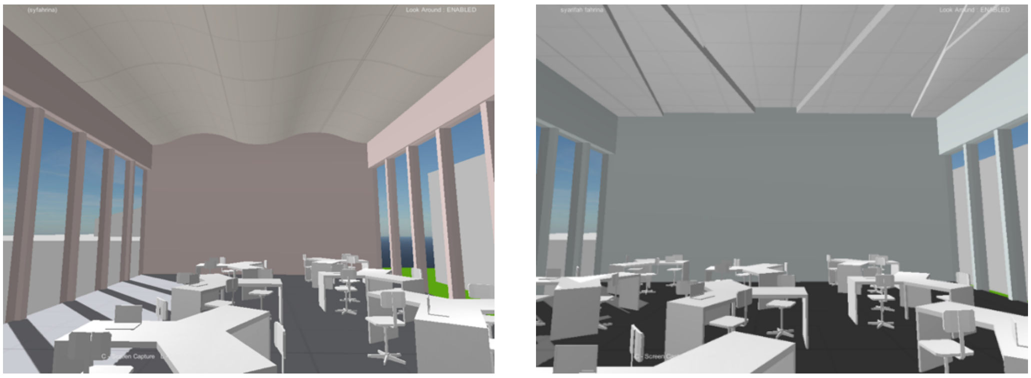
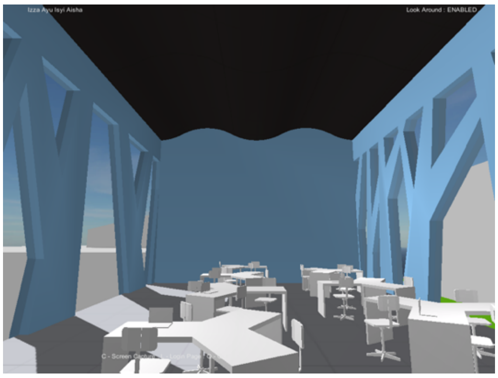


Figure 89. The learning space scene by the Designers 17 in the first stage (left), the second stage (middle), and the responses to Q2, Q3, Q4 (right).
(Source: author)

Designer 17

The designer made six changes in total, in which two were favoured and four unfavoured *(Figure 89).* The favoured were the ceiling colour from Cream to a custom colour near White, and the floor's length Z from 13.04m to 10.88m. The unfavoured was the wall colour from Blossom to Slate, the floor colour from Charcoal to a custom colour near Black, and the floor's length X from 8.8m to 10.88m. Overall, the designer was unfavoured of the preferences of the participants.



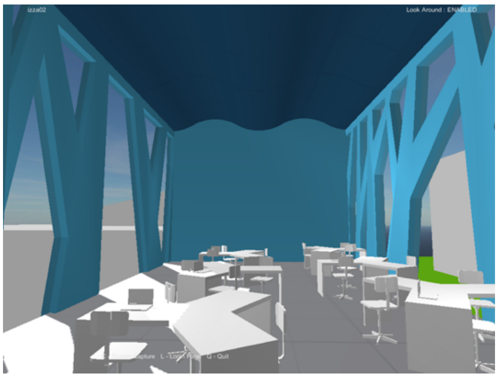


Figure 90. The learning space scene by the Designers 18 in the first stage (left), and the second stage (right).
(Source: author)

Designer 18

The designer made four changes in the second stage, in which the favoured and unfavoured were equal *(Figure 90).* The favoured was the wall colour from a custom colour near Haze to Sky, the floor's length Z from 14.08m to 13.68m. The unfavoured was the floor colour from Slate to Charcoal, the floor's length X from 8.56 to 7.28. In this regard, the designer was neutral.

Summary

Table 9 (below) summarised the professional designers' response to the PDF document. From the eighteen professional designers who have completed the two stages, ten (55.56%) of them were unfavoured, three (16.67%) were neutral, while five (27.78%) designers were favoured to the preferences data gathered from the p-VE. Based on 144 responses, 46 (32.17%) were unfavoured, 58 (40.56%) were Neutral, and 40 (27.97%) were favoured. Designer 11 has the most unfavoured responses (5), Designer 14 is the most consistent with seven unchanged design variables, and the Designer 08 has the most favoured responses (5).

Table 10. Summary of Designers Responses

Designers	Unfavoured	Neutral	Favoured
DS01	●		
DS02	●		
DS03		●	
DS04			●
DS05	●		
DS06			●
DS07	●		
DS08***			●
DS09	●		
DS10			●
DS11*	●		
DS12			●
DS13		●	
DS14**	●		
DS15	●		
DS16	●		
DS17	●		
DS18		●	
	10	3	5

* Designer with the most unfavoured responses (5),
** Designer with the most unchanged design variables (7)
*** Designer with the most favoured responses (5).

7.5. Comparison and Correlation

Spearman's test was conducted to evaluate the correlation between the preference data from all the 186 participants to the eighteen professional designers (Appendix H.3). The correlation test compares all eight variables with a total of 193 components. Apparently, the first stage has a moderate correlation with r=0.561, while it increased slightly on the Second stage with r=0.573. It also appears that the professional designers shared four top-voted components with the all participants choices, they are the Ceiling style (CType03), the Windows-style (WType03), the Ceiling height (4 – 4.9m), and the Ceiling colour (White). These four top-voted components remained unchanged on the second stage.

Table 11. Summary of Top-Voted Components Comparison
(All participants/ Designers 1st/ Designers 2nd stage)

		All Participants 186	Designers1st 18	Designers2nd 18
Style/Type	Ceiling	Ctype03		
	Windows	WType03		
Length	X	8 – 8.9m	8 – 8.9m	13 - 13.9m
	Z	8 – 8.9m	16m	
	Ceiling Height	4 – 4.9m		
Colour	Ceiling	White		
	Floor	White	Charcoal	White
	Wall	Duck egg	Blue	

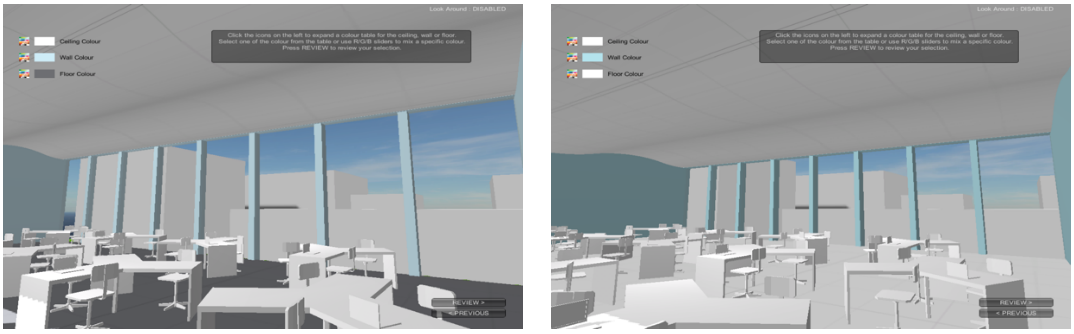


Figure 91 The Amalgamated Scene Comparison Designer 1st (left) and 2nd stage (right)
(Source: author)

Chapter 08
Findings and Discussion

8.1. Feasibility and Usability

During the Piloting test and the two-stage experiment, the proposed method implemented as p-VE had been made accessible to everyone, in that it enabled the participants from different backgrounds, locations, and skills to express 'what a learning space should look like'. In this study, the p-VE has been accessed by participants from various locations (the UK, Indonesia, Japan, Thailand, and Australia), and it was available anytime during the experiment. In total, there were 186 scenes created and made accessible to the participants, or the experts, to reflect their decision making, and the data can be linked to the user demographic data whenever required. Technically, the experiment has demonstrated the feasibility of coping with a potentially large number of participants. Compared to the Piloting test, which had only 19 participants, the first-stage experiment received nearly ten times as many participants. The only technical problem encountered was the change in the Web technology used by p-VE during the experiment, where popular Web browsers were withdrawing support for the technology used by Unity Web-player. Consequently, some participants had a problem when installing the Web player required to run p-VE. Therefore, it was inevitable that in order to keep pace with the ever-changing technology, working seamlessly with popular Web browsers, achieved large-scale participation by anyone, anytime, anywhere.

The usability test results also confirmed that the participants were in favour of the usability of p-VE, in which the majority of the participants agreed the platform is easy to use (75.21%). Considering the participants have never previously used the platform and most do not have previous design experience, the finding is surprising. The procedure to run the platform itself is not straightforward, whereby a web player needs to be installed beforehand, and yet the participant still needs to familiarize him/herself with the navigation. However, with a strong score of 5.43, it received. For comparison, the platform developed by Drettakis received 4.7 mean scores for the ease to use, although it was built for the urban environment. The nearest comparison that was built for Interior space is the one developed by Vosinakis et.al. It received 6.09 mean score for navigation aspect, however, it did not receive an evaluation for the ease to use aspect. 66.94% agreed it had adequate support information, and 72.73% agreed it took an adequate amount of time to complete. In the first stage, all participants took 7.94 minutes on average to complete the tasks. The participants moderately felt adequately supported to express their preferences. This can be judged by the percentage of participants that felt supported to express their preferences for the Spatial dimensions (60.33%), and Element style (62.81%). Only the Surface colour function received less than 50% with 47.93%. Although the results are positive and show some improvement compared to the pilot test, there is plenty of room for further improvement. Surprisingly, a high percentage of the participants (91.4%) felt confident about using p-VE to express their visual preferences, with even 52.2% being highly confident. In the second stage, a high percentage of the designers (88.89%) agreed that the visual analytics from the first-stage experiment, as presented in the Visual Analytic document supplied, was easy to understand with mean score 3.55. It should be noted that 72.22% of the designers thought that the visual preference survey data posed a restriction on design creativity. However, they also generally agreed that knowing the results from the first stage has influenced their design decision-making during the second stage.

The Instrument

The design of the p-VE was supposed to respect the user-centred principal, in which the user's need and requirement are paramount. Expectedly, the users always wanted more, more features, more choices, more colours. The question is when it will be enough? How many is enough? How many colours should be available? Although the experiment showed that providing more colour choices do significantly improve the users' satisfaction on the surface colour function from 4.29 to 4.41 (scale 1 to 7). For a method aimed for the early stage of the design process, it is recommended that each variable should consist only 3 to 11 choices need to work effectively.

Despite numerous methods and tools have been developed with similarities in technology (i.e. virtual environment) and purpose (i.e. interior spaces, learning spaces design, large-scale participation), principally it still difficult to make an apple-to-apple comparison, as they employed a various method to evaluate their system.

8.2. The Preferred Learning Space Design

The Wall colour was the most disparate in comparison to the other results. None of the colours received more than of the 10% votes for the Wall Colour category, which makes no ideal situation for decision-makers. In this case, however, Blue and Breeze have similarities in tone to Duck egg, which together makes 18.61% of the vote. The finding supports the suggestion to use cool colour in the learning environment (Mahnke 1996b; Engelbrecht 2003).

For the Ceiling colour, White is the top-voted with 15.64% of the share of the votes. White was also the top-voted colour for the Floor colour, with 10.56% votes, whilst Charcoal follows tightly behind as the second preferred colour, with 10%. For the spatial dimension results, in the experiment, the range 8 - 8.95 m was the top-voted for length for both sides. In the introduction of p-VE, it was mentioned that the learning space is intended for 20 occupants, which might have influenced the participant's decision. The result is consistent with, if not a little over, Hall's (1988) public area proximity range of 3.6 - 7.6 meters[2]. For the Ceiling height, the top-voted range is 4 – 4.95 m, which in this case might closely relate to the floor area choice. For the Window style, the top-voted window style in this study has the most opening areas to view out, which is not surprising, according to various literature. For the Ceiling style, the Wavy style is the top-voted. Although this type is not a typical flat ceiling, this style has become very popular in the last few decades, especially in leisure buildings.

Table 12. The Top-voted visual variables by all participants

Style/Type	Ceiling	Ctype03
	Windows	WType03
Length	X	8 – 8.9m
	Z	8 – 8.9m
	Ceiling Height	4 – 4.9m
Colour	Ceiling	White
	Floor	White
	Wall	Duck egg

The Amalgamated

Based on the results of the first stage, a scene was collated using all the top-voted visual variable values collected from all the 186 participants in the first stage, as showed in *Figure 92*. In compare to the appearance of some of the Scenes submitted by the participants *(Figure 49)*, it appears that the amalgamated scene is more subdued. Although the visual quality does coincide with Berlyne's theory, which suggests that environmental quality should keep arousal levels neither too high or too low for the occupants to perform well. In addition, adolescent students are known to prefer subdued colour than young children (Engelbrecht 2003). Considering that many other visual variables did still not make it into the p-VE, the outcome could have been different.

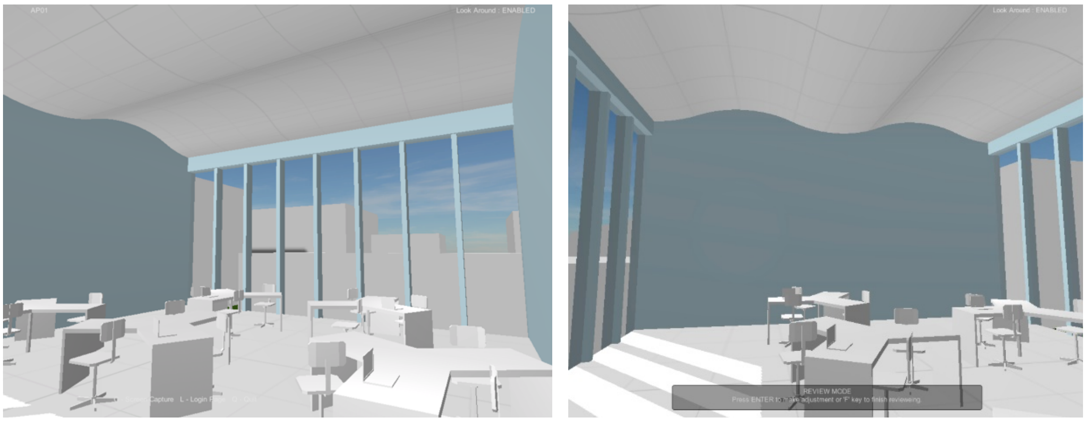


Figure 92. The scene of the learning space collected from all the top-voted visual variables values from all participants
(Source: author)

During the experiment, a few participants also reported discrepancies between the colour in the colour-pallet and the applied colour on the surface. It turned out that the different shading on the surfaces had misled the participants, in which they could not tell which one was the correct colour. In this case, the participants faced the surface behind the light source, and what they were seeing was a shaded surface that had a darker colour rendition. This problem had been reported by a volunteer, who in turn asked the participant to look around to apprehend how the shading had affected the perceived colour of the surface. Once they understand the concept, they will learn how to strategically position themselves in the interior space and find a scene where they could see most of the surfaces.

Default Effect

However, all set of options that participants choose from in the p-VE have a default value, which is required to generate the virtual environment. For example, the default value for the wall colour in this study is set to be white, which need to be pre-defined to display the wall properties correctly. However, the use of default option has been identified to cause participants to end up with the value if they do not choose active choice. Microsoft design manual stated that a default selection should be avoided if the goal is to collect unbiased data (Microsoft n.d.). In this study, the results from the p-VE showed that 5 out of 8 variables have the default value as the top-voted. They are the Floor's length X (8 - 8.9m), length Z (8 - 8.9m), Ceiling height (4 – 4.9m), the floor's colour (White), and the Ceiling's colour (White). Since it is not possible to accurately read the participant's mind, there are few possibilities on why the participant chooses the default values:

a) The participant agreed with the default value i.e. the default option is within his/her range of choices and made the easiest choice.
b) The participant was undecided over the range of choices, thus left it unchanged.

The Design and Non-Design Background Comparison

The comparison results through p-VE showed that both groups are correlated, regardless of the participant's experience in design education. Both groups share a strong correlation on their usability test (r=0.786) and have a moderate correlation in preferences (r=0.614). They also share the same top-voted components on four of eight design variables included in the p-VE design. It is important to notice that the proportion of both groups in this study is greatly unequal with roughly three Non-design against one Design background.

The previous study found that the public dislikes the atypical style (Stamps III and Nasar 1997) is not supported by their preference on the ceiling style. The results show that the Non-design chose a playful ceiling style (CType03), while the design group chose the ceiling with skylight (CType05). Presumably, since the Design group preferred the presence of skylight. Also, both groups have a strong correlation for the window style and chose WType03, which is typical in style with a wide opening. For the wall colour, although each group has chosen a different colour (Blue and Duck egg), both colours nearly look identical in the scene.

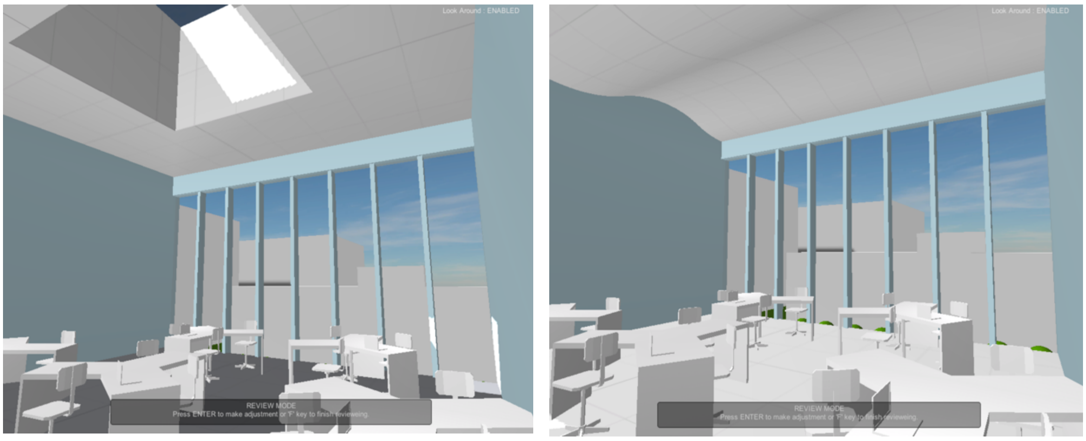


Figure 93. Two scenes collated from the top-voted variables by the Design group (left) and Non-Design group (right).
(Source: author)

The preferences results showed that most groups are correlated, and even shared similar top-voted components of the design variables. The male and female participants are moderately correlated, as well as the participants from Indonesia and the UK.

8.3. The Professional Designer Responses

Based on the Second-stage results in Chapter 7, there is a disconnection between the assessment result and the two-stage experiment. The results showed that despite the most of the professional designers were strongly agreed the Visual Preference data had influenced them, nine (50%) designers claimed they could take a different direction to develop the design. The designer responses in the two-stage experiment also showed similar results, in which 32.17% of design decisions made on the second stage were unfavoured to the users' preferences data. The study did not investigate further how the result influenced the designers, and thus cannot provide an exact explanation. There are several possibilities:

- The designers are creative experts that are always 'standing out' from the crowd, thus they have consciously take a different path.
- Despite the reliability-coefficient showed that the questionnaire as highly reliable, *responses-bias* could have caused the participant to respond to questionnaire inaccurately.

Chapter 09 Conclusions and Recommendations

9.1. Conclusions

The study has completed the design of a method to facilitate a diverse population in expressing visual preferences in the early stages of learning space design implemented it as p-VE and tested it using the Usability test. The method was implemented as an online interactive 3-D modelling application called p-VE. Based on the reliability of the p-VE during the experimentation, the author has a firm belief that larger-scale participation can be facilitated using the proposed method. It employs 'Matching' (as a way to express preferences) from the Visual Preference Survey, in which the participants (students and others) collate a preferred scene of learning spaces by altering the attributes of the visual variables featured in the p-VE. The parametric modelling approach received positive responses from the participants, in that they felt moderately supported in expressing their visual preferences, regardless of their skill level. In the development of a new learning facility, the students and those who are impacted by the development can visually participate in the design process, anyone, anywhere, anytime. And the results can quickly be generated to inform the designers and the decision-makers. However, p-VE still requires tremendous works to improve in many aspects. Some of them will be further discussed in the limitations section.

The study has also conducted the two-stages experiments, which bring out the visual-preferences data for the learning spaces and the usability-test outcome. The visual preferences data also revealed the relationship between groups among the participants. In regard to the professional and non-designer relationship, it appeared they are moderately correlated. Does it mean that they do not actually differ in preferences? Some people may argue that it shows the designer can guess the layperson's preferences. Can they?

To assess the professional designer's valuation on the proposed method and tool, and their responses to the participants' result. Despite the professional designers declared to have been influenced by the results from the first stage in making decisions for the second stage, half of them stated that they would develop the results in a different direction. That could be why the designers' responses were not in favour of the users' preferences. Since Some outcomes cannot be explained exactly related to the study, which may explain the nature of the designers themselves, in that they are known to be proud of standing out in the crowd or at least try to be original. Consequently, the designers could also use the results to develop the design in different directions, as long as they have the guidance of what to follow and what to avoid, the design outcome should still be within the users' expectations.

9.2. Contribution

This study has demonstrated the development and evaluation of an approach allowing the end-users to actively participate in expressing preferences for learning spaces in the early stage of the design process. The challenges, the findings, the advantages, and the drawbacks can be valuable for future study. Considering that it took nearly three years just to produce a working prototype, there was a doubt whether a non-programmer (e.g. architect, designer) can implement the method. In this study, the author spent nearly three years to design and develop the p-VE without previous programming experience. The lack of resources also contributed to the requirements that the development tools need to be easy to use, learn, and also accessible via open sources and similar i.e. freeware, shareware, trialware. Although, they do have drawbacks. With experiences, it is possible to significantly reduce the development time to matter days. Therefore, this study contributes to light up the path that some may find it helpful. In the future, it would be plausible if a developer can build a plug-in for SketchUp that can greatly increase its efficiency.

In developing a similar platform, the author suggests that the purpose of the preliminary study should be about also defining the design variables that participants feel the need to be changed, rather than merely based on the importance of its presence. The default effect found in this study could be an indication that although the participant has judged a variable as important, it does not mean they feel the importance to make a suggestion. In order to avoid the default effect, when the default value must be predefined:

a) Use an unpopular value or component to force the participant altering the variable. In this study, the default effect mostly appeared at the variables that have ‘popular’ default values.
b) Random the appearance order of the default setting.

The participants with self-declared design backgrounds, in general, agreed that the results from the first stage were somehow influential for their decision-making in the second stage. Based on this result, the study proposes a model of *user-designer partnership* in designing learning spaces. The partnership can be initiated by launching a large-scale visual preference survey for anyone interested in learning spaces to participate; anywhere, anytime. If the survey is implemented as a Web-enabled interactive application, real-time visual analytics can be generated from analysing the visual preference data collated and made accessible to design practitioners. Design practitioners can play an active role in shaping the front-end design of the application to provide an engaging parametric, navigable, 3-D, virtual environment. On the other end, participants are supported by the application to play with the parametric modelling freely and generate preferred outcomes to their own liking, which in effect can be seen as *collective creations* by design practitioners, to engage with reflective practice.

What Next? A model of user-designer partnership

As well as the feasibility and usability, the process carried out in this study also demonstrated a model of user-designer partnership at the early stage of the design development process, in which a generic virtual environment was used as the presentation layer. As the design development progressing to the next stage, the process can be repeated by employing a modified version of the p-VE, which accommodate the results from the previous survey. For example, in the next stage, the colour choices can focus on only a few top-voted colours, the geometric shape of the spaces can also be more site-specific. The process then is repeated whenever required to reflect dynamic relationships between users and design practitioners *(Figure 94)*. The partnership can involve various parties from the developer, the designers, users, and the community who shares a similar interest in the development and agreed to actively involved in the process. The challenge is to change the mindset of the designers to consider other parties as creative partners.

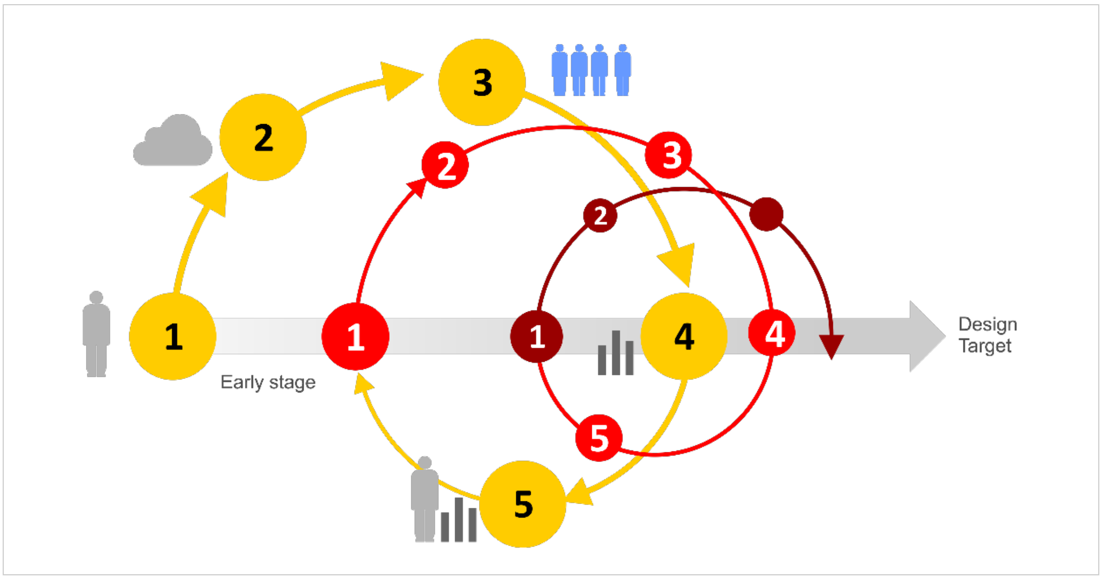


Figure 94. Model of user-designer partnership
(Source: author)

A model of user-designer partnership:

1. Designers initiate large-scale visual preference survey designed to attract participation from anyone, anywhere anytime. The survey could be project and site-specific or topic/ theme-specific.
2. Development and deployment of an online interactive p-VE platform to implement the L-VPS
3. Participants expression of visual preferences
4. Software agent collating user-expressed VP into real-time visual analytics
5. Designers engage with the visual analytics and user-constructed VP scenes
6. Designers start from 1 again as moving to different stages of the design process

The implementation of p-VE can be expanded to another type of commercial spaces like offices or other indoor spaces used by many occupants. In the early stage of the design development process, the generic virtual environment is open to different interpretation.

9.3. Limitations

A Usability test was conducted involving participants to express their subjective evaluation during a 'scenario' for the p-VE. In hindsight, this test should have done by an independent evaluator, who also responsible for gathering the participants. Unfortunately, in this study, the author also took the responsibility to conduct the usability test. Thus, there is always a concern of bias in the test result, especially when the participants have any connection to the researcher. In this research, however, most of the participants were not contacted directly by the researcher, and the experiment was done remotely using online technology that makes it unlikely for the participant to get influenced by the researcher. The researcher takes the moral ground that none of the data has been altered to favour the outcome of this study.

The subjects in this study were selected randomly to represent an entire group of higher-education students and design professionals. Both groups are essential to evaluate the p-VE and for the Learning Space design. The researcher did not make a particular effort to control the proportion of the group or the participant's qualification, i.e. how long has the designer work as professional. Consequently, the data availability of some groups lacks to conduct a reliable demographic comparison.

The current state of implementation of p-VE maybe just a small part of what was supposed to be a bigger plan. Currently, it features only a fraction of the potential variables for further development. This study has been hindered by time and resource limitations in completion. the outcomes of the implementation and the survey have been limited. Unexpectedly, the development of the p-VE took a larger proportion of the time. Initially, a programmer was involved but dropped out at the crucial moment. It is believed that the number of participants could have increased considerably with a better-resourced campaign for wider and sustained participation.

The comments and feedback left by the participants showed their desire to see the application to have more features, such as more colour, added textures, more window styles, and so on. Although the author agreed to provide as many features as possible, it needs to be done effectively, since involving more data means more work at the back-end. Even for the current version, the researcher struggled to manage all the responses. As Townsend and Kahn suggest, providing too many variations could lead to a choice overload (Stamps III and Nasar 1997), which the method tried to avoid.

The implementation of the p-VE relies heavily on the open-source community which unfortunately susceptible to changes. At the time of writing, most of the development tools used in this research are still fully functional, except Parse that appears to be shut down on the 28th of January 2017. However, they release a few migration tools that allow its users to build their own *Parse* server and use it for online data storage. Alternatively, there are a few others offering similar services.

9.4. Recommendation

For further study I, intend to investigate:

1. How the experiment with a generic learning space can be extended to a site-specific context and its implications for the users. As previously discussed, user involvement can happen in different stages. Therefore, it is possible to employ the method in different stages, which requires the adoption of the parametric virtual environment in a site-specific context. For example, in the pre-occupancy stage, in which the organizer would like to involve the students to suggest a new appearance for the current learning spaces, and how the changes will have an implication on other variables i.e. Consequently, the features need to be customized to meet the requirements and limitations.
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. During the study, most of the data analysis needed to be done manually, which impacted upon the starting time of the second-stage. Also, it is known that one of the liabilities of large-scale user participation is the daunting prospect of dealing with a large number of data. Unity 3-D has the capability to process and analyse, and it can also visualize the data using its a scripting language, which unfortunately needs time to implement. Another possibility is to link the data to an online data visualisation tool that can generate infographics.
3. The potential of the collection of scenes has not been explored yet. Perhaps they can benefit from another form of participation, such as crowdsourcing, involving the stakeholders rating the scene that they think is going in the right direction. In collective design, the p-VE can facilitate a community to work together to rate the design of another member. In that case, a p-VE that enables the participants to view and rate the collection of scenes could assist the decision-makers.

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APPENDICES

Appendix A. Workflow of P-VE

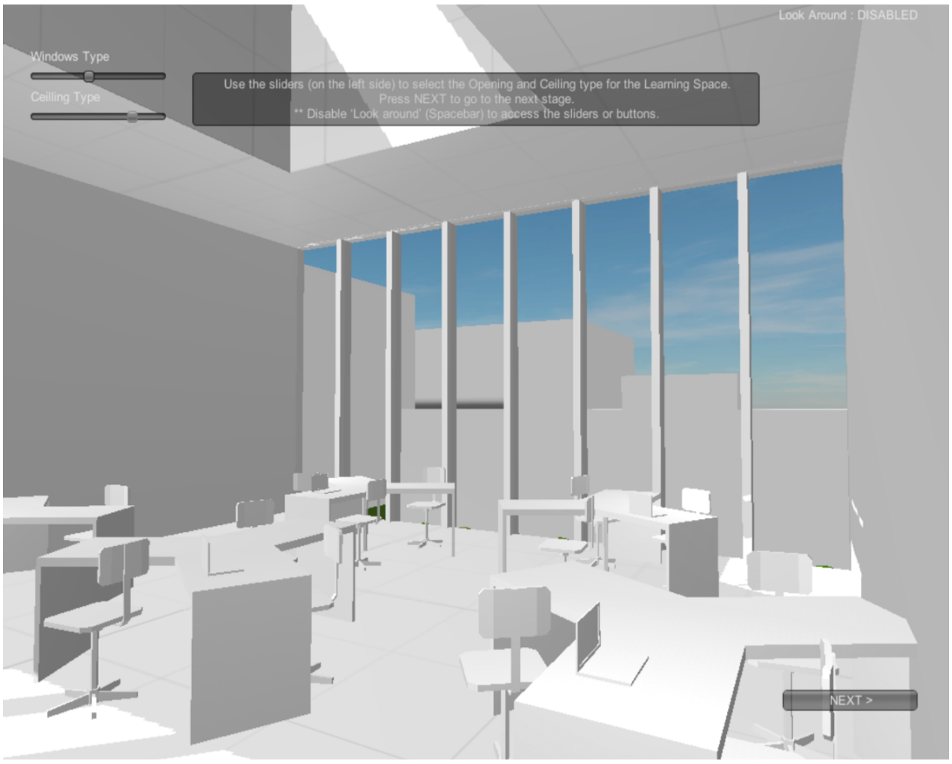
Introduction Page

Signup/Login Page

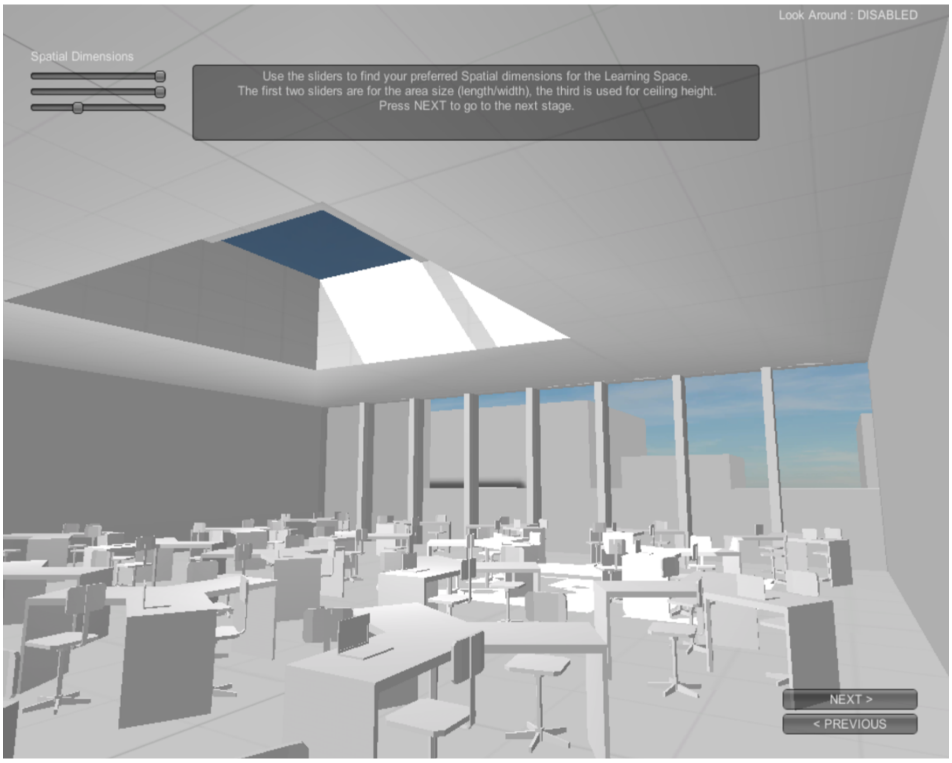
Demographic/User Profile Page

Navigation-helper

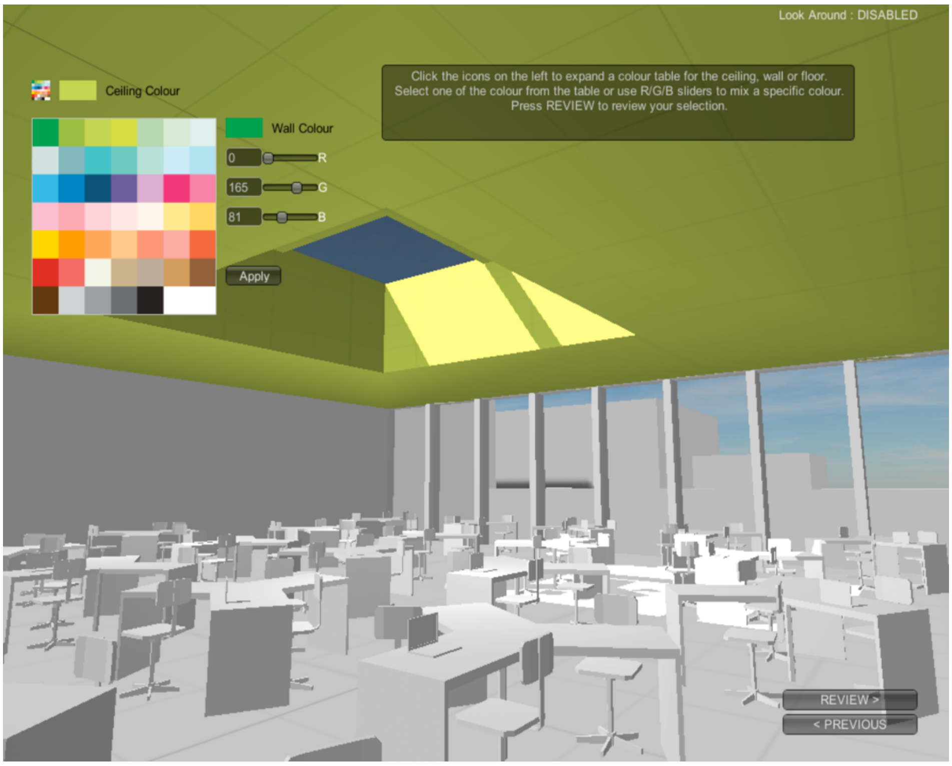
Element Style Page



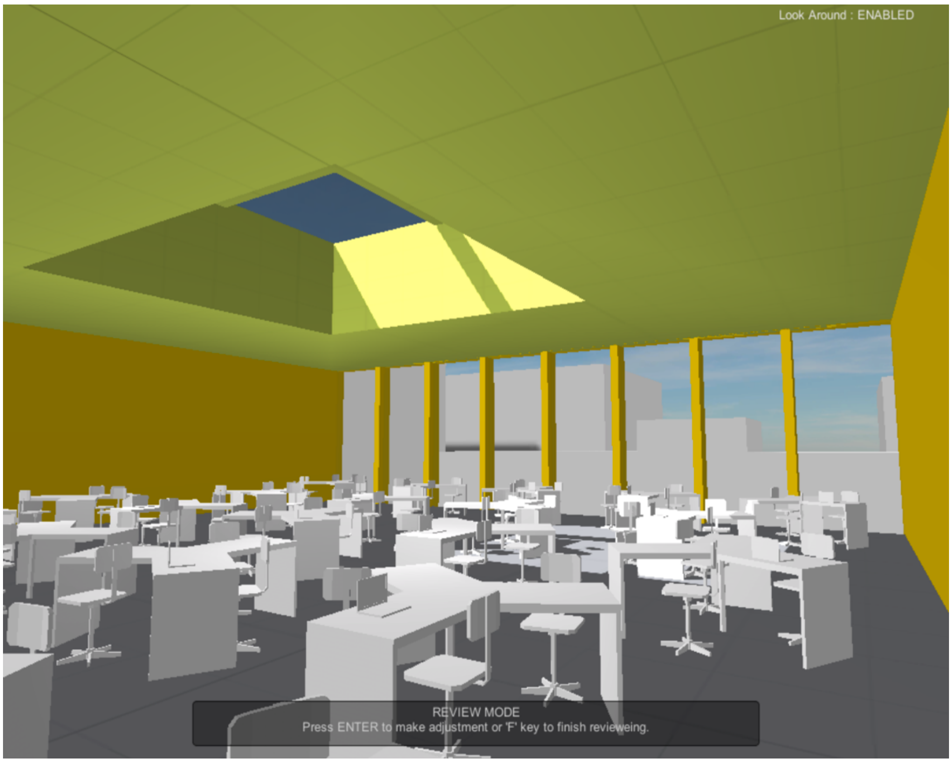
Spatial Dimension Page



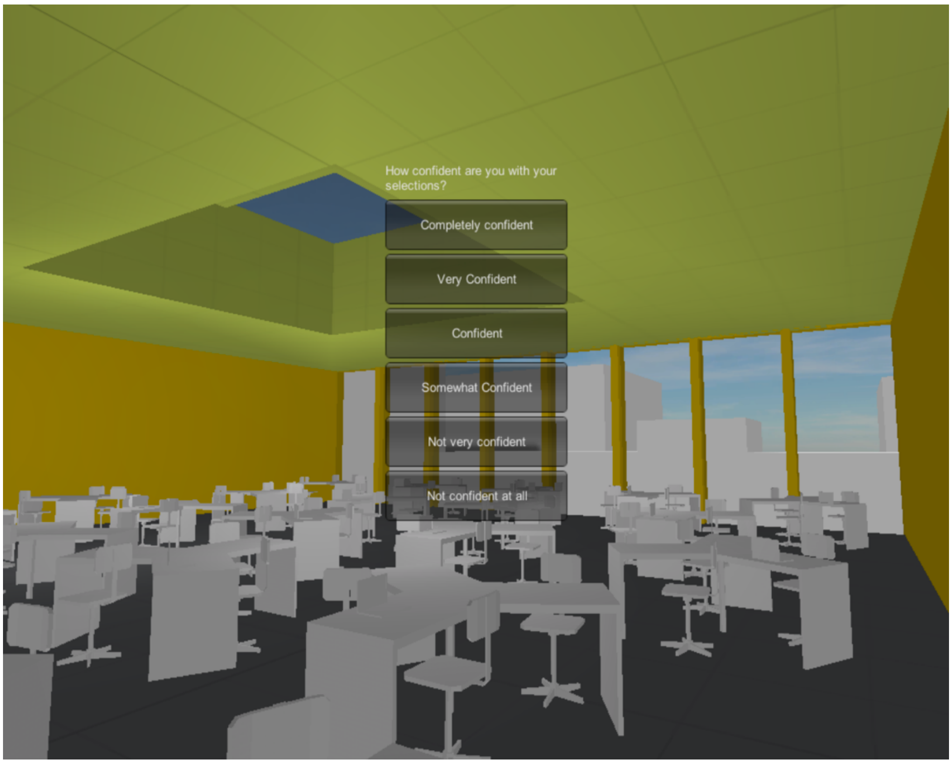
Surfaces Colour Page



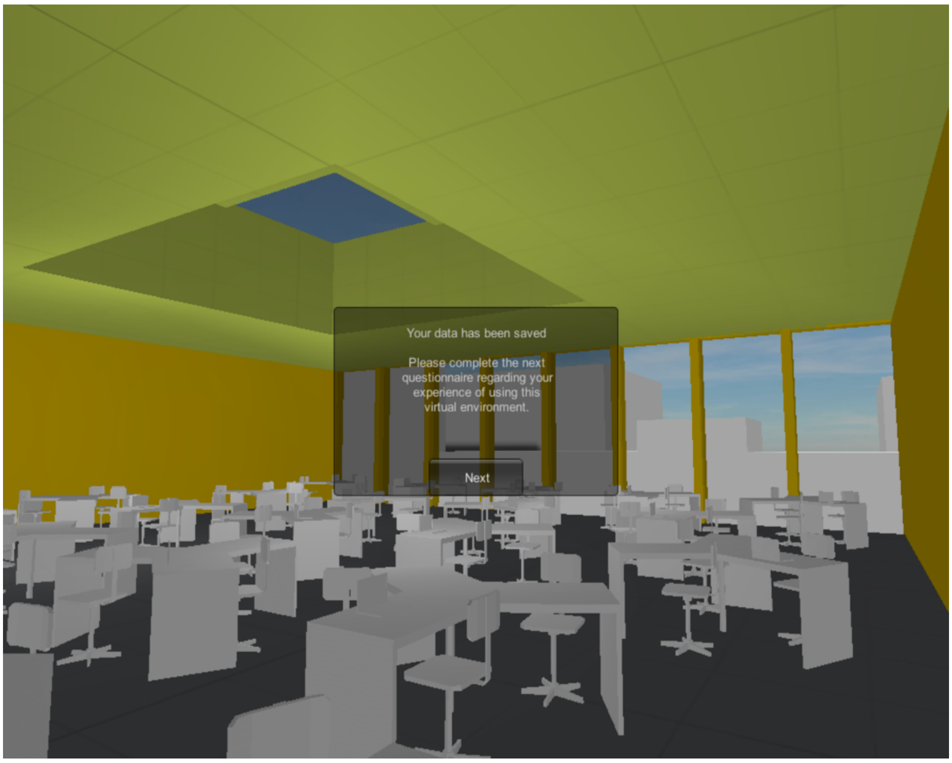
Review Page



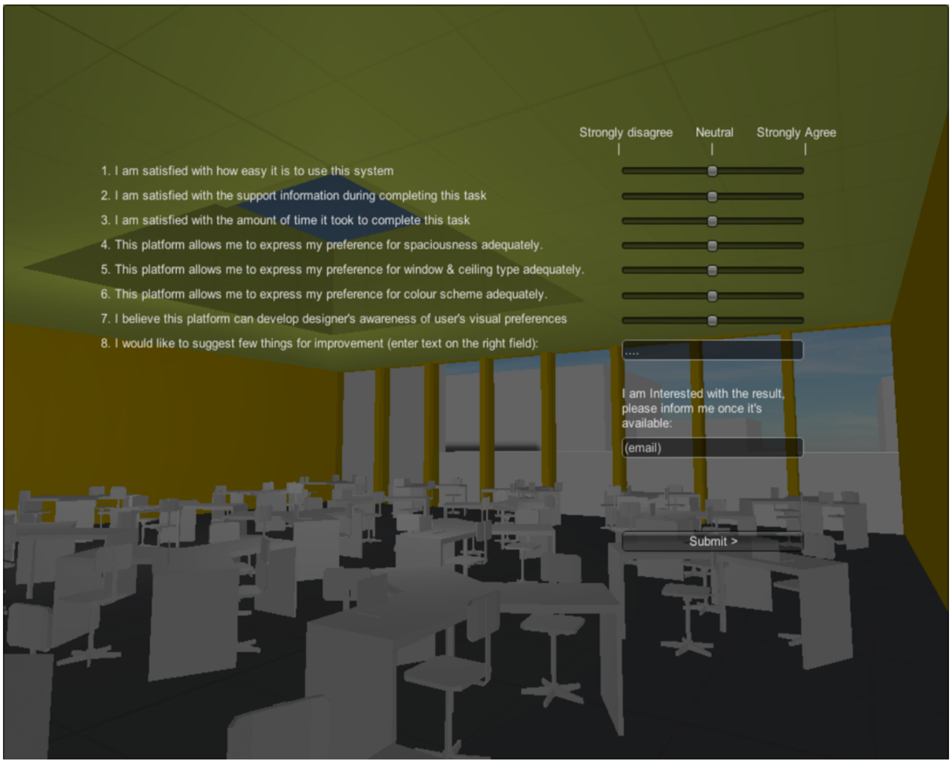
Confidence Rating Page



Tasks-Completion Notification Page



Questionnaire Page



A video of the P-VE can be accessed through the following link
https://youtu.be/2_y-17YLaZwh

Appendix B. Colour Pallet

No		Name	RGB Value Red	Green	Blue
1		Grass	0	165	81
2		Apple	153	194	72
3		Green	194	216	90
4		Lime	211	223	79
5		Mint	182	219	175
6		Pistachio	217	217	213
7		Breeze	223	223	236
8		Mist	210	226	225
9		Haze	135	184	188
10		Ocean	86	195	200
11		Turquoise	115	202	193
12		Spearmint	187	225	214
13		Duck egg	206	236	247
14		Blue	180	227	237
15		Sky	77	184	228
16		Aqua	4	130	191
17		Navy	29	81	120
18		Purple	112	89	157
19		Lilac	218	172	208
20		Rose	237	37	123
21		Pink	243	126	168
22		Musk	248	189	209
23		Petal	248	168	181
24		Dusty Pink	251	210	216
25		Blossom	253	232	229
26		Cream	255	247	236
27		Lemon	255	235	149
28		Buttercup	255	216	105
29		Yellow	255	217	0
30		Orange	249	157	30
31		Peach	249	167	94
32		Apricot	253	202	139
33		Coral	248	150	121
34		Tulip	249	170	165
35		Poppy	238	101	69
36		Red	219	32	41
37		Rouge	238	104	105
38		Vanilla	242	244	230
39		Latte	200	181	141
40		Almond	189	173	158
41		Beige	207	159	97
42		Brown	143	97	61
43		Choc	97	57	21
44		Grey	209	210	212
45		Slate	158	159	163
46		Charcoal	109	110	114
47		Black	36	32	31
48		White	255	255	255

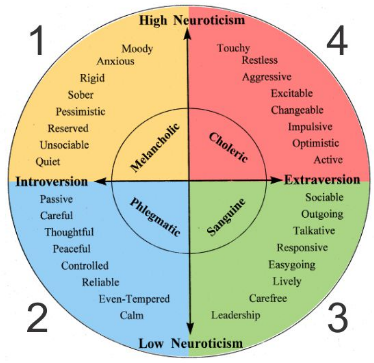
Appendix C. Preliminary Study

C.1. Questionnaire Design

About yourself:

01. Which area in the diagram below represents your personality?
Not Sure

a. 1
b. 2
c. 3
d. 4



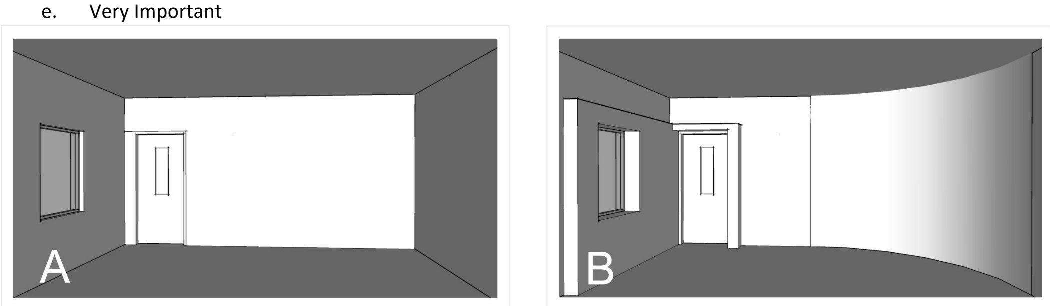
02. Where do you spend most of your time in the last 5-10years?

a. Asia
b. Middle East, North Africa and Greater Arabia
c. Europe
d. North America
e. Central America and the Caribbean
f. South America
g. Sub-Saharan Africa
h. Australia and Oceania
i. Others

How important is each following visual variable in affecting your experience and performance during learning activity?

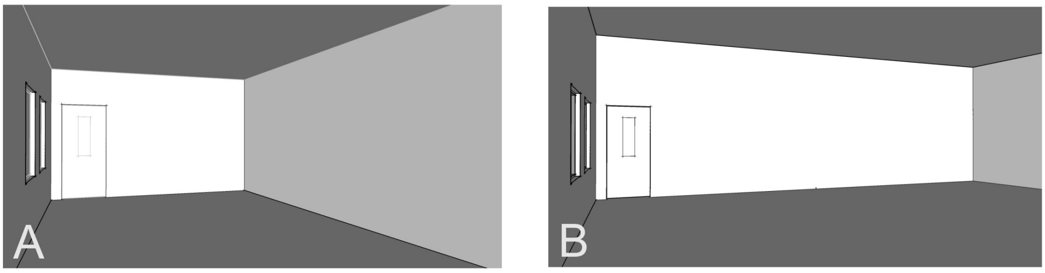
03. Sense of Shape/ Geometric Shape:

a. Unimportant
b. Less Important
c. Not Sure
d. Important
e. Very Important



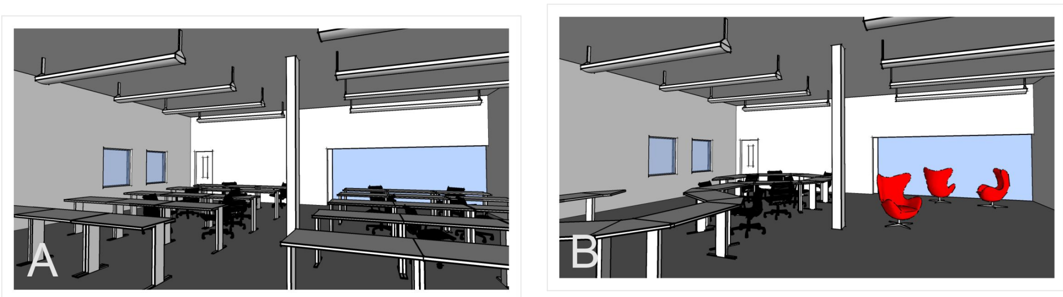
04. Space Quality: Scale

a. Unimportant
b. Less Important
c. Not Sure
d. Important
e. Very Important



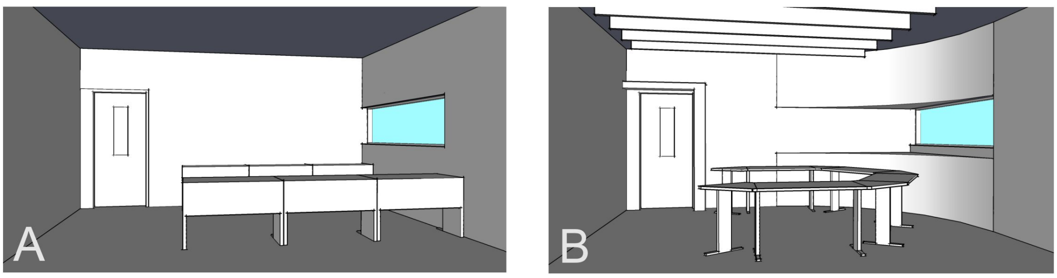
05. Spatial Organization

a. Unimportant
b. Less Important
c. Not Sure
d. Important
e. Very Important



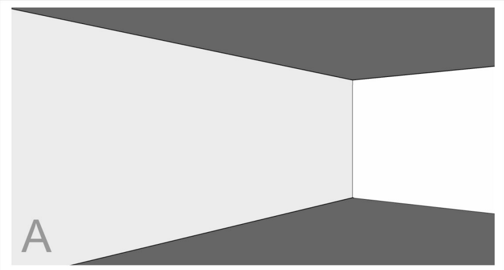
06. Complexity of Visual elements

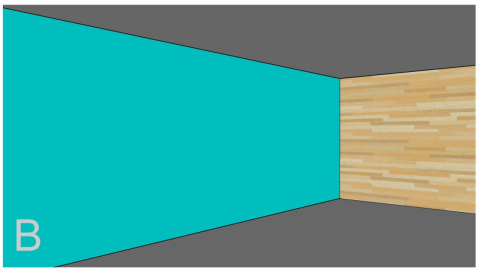
a. Unimportant
b. Less Important
c. Not Sure
d. Important
e. Very Important



07. Surface Colour, Texture and Pattern

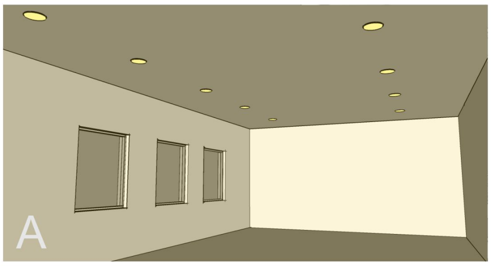
a. Unimportant
b. Less Important
c. Not Sure
d. Important
e. Very Important

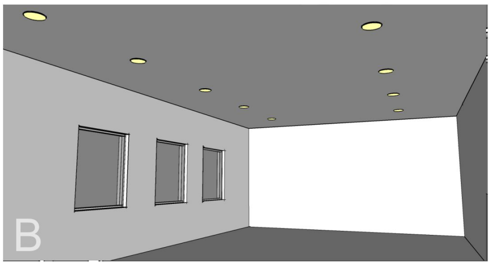




08. Lighting Quality

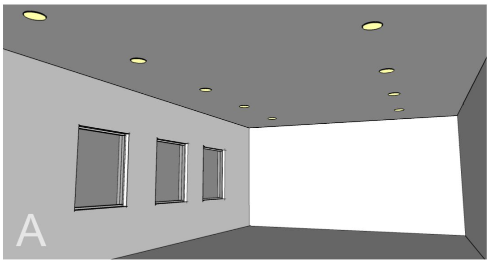
a. Unimportant
b. Less Important
c. Not Sure
d. Important
e. Very Important

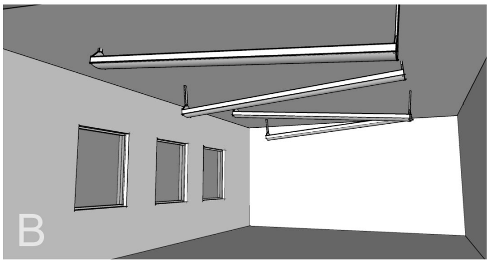




09. Lighting Composition

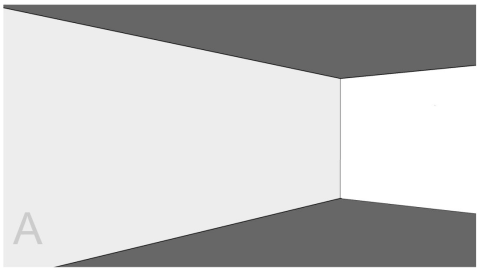
f. Unimportant
g. Less Important
h. Not Sure
i. Important
j. Very Important





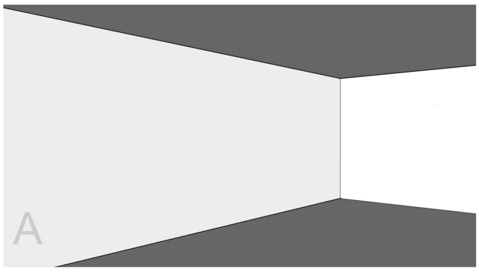
10. Presence of Plants

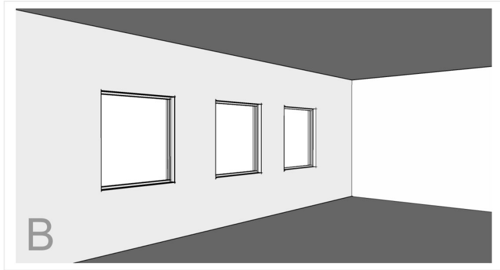
a. Unimportant
b. Less Important
c. Not Sure
d. Important
e. Very Important



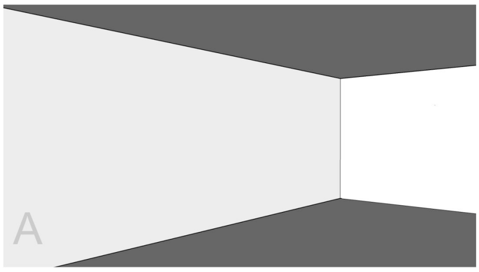
11. Presence of Windows

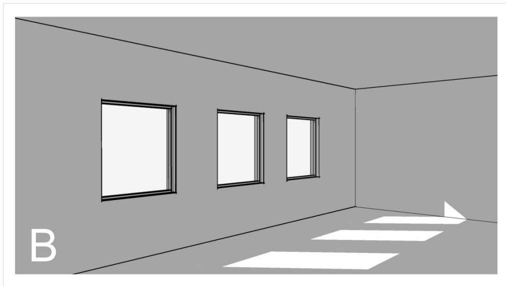
a. Unimportant
b. Less Important
c. Not Sure
d. Important
e. Very Important



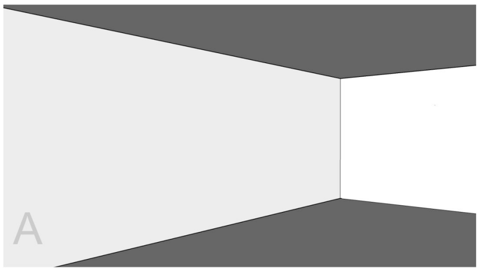


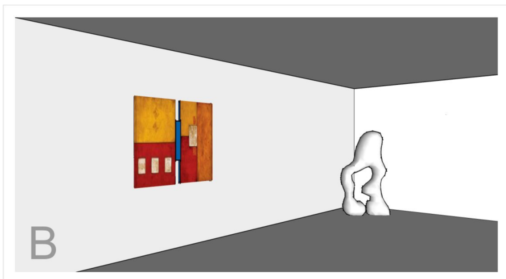
12. Natural Light
   a. Unimportant
   b. Less Important
   c. Not Sure
   d. Important
   e. Very Important





13. Presence of Arts: Painting/ Sculpture
   a. Unimportant
   b. Less Important
   c. Not Sure
   d. Important
   e. Very Important





14. Visual variable/s not mentioned above, which in your opinion need to be considered

C.2. Preliminary Study Results

Reliability Statistic

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.756	.804	11

Statistic – Sorted by Mean Score

		N		Mean	Median	Mode	Std. Deviation	Variance	Skewness
		Valid	Missing						
1	Natural Light	23	1	4.52	5.00	5.00	.59	.35	-.81
2	Windows	23	1	4.35	5.00	5.00	1.11	1.24	-2.94
3	Surf Colour	23	1	4.26	4.00	5.00	.92	.84	-1.35
4	Space quality	23	1	4.22	4.00	4.00	.85	.72	-1.43
5	Spatial Org	23	1	4.22	4.00	5.00	1.00	1.00	-1.38
6	Light Type	23	1	4.13	4.00	4.00	.76	.57	-.92
7	Shape	23	1	3.83	4.00	4.00	.94	.88	-.35
8	Complexity	23	1	3.65	4.00	4.00	1.07	1.15	-.43
9	Plants	23	1	3.30	4.00	4.00	1.15	1.31	-.46
10	Art	23	1	3.30	4.00	4.00	1.26	1.58	-.49
11	Light Comp	23	1	2.87	4.00	4.00	1.94	3.75	-.58

Appendix D. Piloting Test Results

D.1. Usability Test

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.82	0.83	7

Item-Total Statistics

	Scale Mean if	Scale Variance	Corrected Item-	Squared	Cronbach's
Q01	28.24	46.32	0.53	0.74	0.80
Q02	27.94	47.06	0.54	0.69	0.80
Q03	27.53	46.39	0.66	0.78	0.78
Q04	28.12	43.36	0.63	0.84	0.78
Q05	28.18	42.78	0.57	0.86	0.79
Q06	28.41	43.51	0.51	0.54	0.80
Q07	27.82	49.78	0.52	0.69	0.80

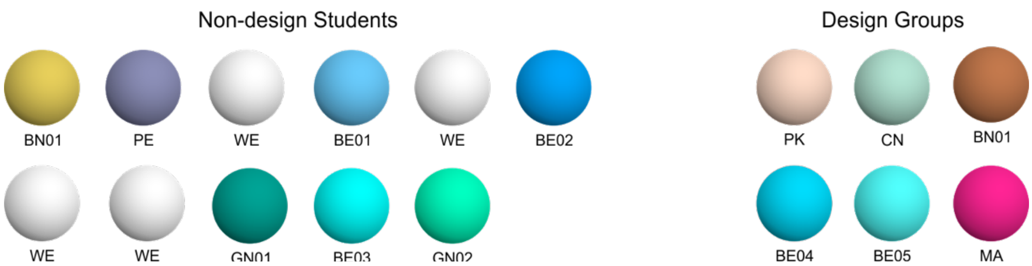
Item Statistics

		Q01	Q02	Q03	Q04	Q05	Q06	Q07
N	Valid	17	17	17	17	17	17	17
	Missing	0	0	0	0	0	0	0
Mean		4.4706	4.7647	5.1765	4.5882	4.5294	4.2941	4.8824
Median		4.0000	5.0000	5.0000	5.0000	4.0000	4.0000	5.0000
Mode		4.00	4.00	4.00	4.00[a]	4.00	4.00	4.00[a]
Std. Deviation		1.58578	1.48026	1.33395	1.69775	1.87475	1.92888	1.21873
Skewness		-.152	.065	.174	-.475	-.439	-.177	.251
Std. Error of Skewness		.550	.550	.550	.550	.550	.550	.550

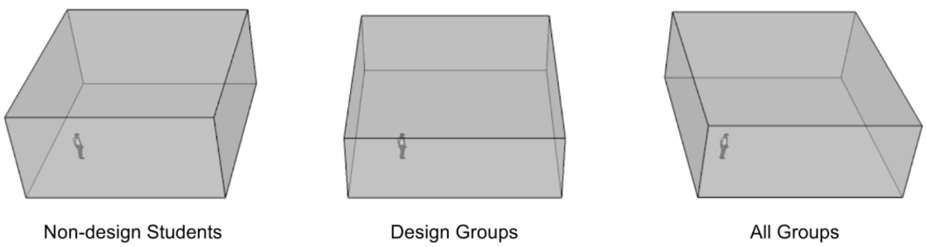
a. Multiple modes exist. The smallest value is shown

D.2. Preferences Data

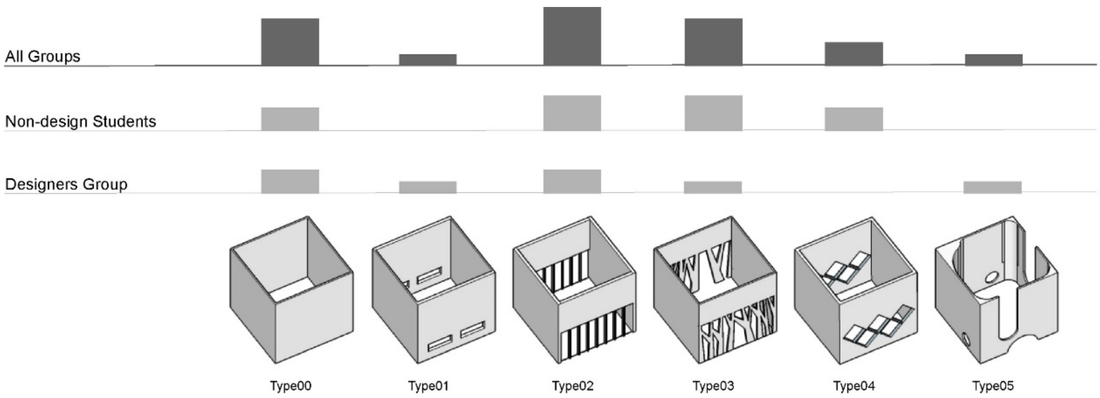
Wall Colour Preferences



Spatial Dimension Preferences



Window Styles Preferences



Comments and Feedbacks

	Comments	English translation
1	*Warnanya masih kurang / pengen banyak warna / masa dikasih cuma 3 warna* *uda itu jelek pula pilihan warna / g ada nilai seni orang yg buat simulasi / jendela jelek coraknya /* *pilihan sedikit / gak bisa modif / masa bentuknya gitu / pattern jendela sedikit / yg banyak donk /* *victorian style / kaca nako / 10-20 uda cukup / ini cuma 3 / dikit / minimal 10*	The participant felt that three colours (Red/Green/Blue) are too limited and unfavourable. (note: although, the colours can be mixed to create a secondary colour). The participant also suggests that three windows variations (note: actually 5) are too limited and suggests 10-20 variations.
2	Good in expressing a preference in general for common people, although there are some errors while using it (technical problem). Perhaps would be more helpful for people to be given some other objects that could help them feel the room atmosphere (i.e. series of tables and chairs, people sitting and reading, etc), so that they can directly consider the provided objects with the design elements that they choose (windows, walls, ceiling, etc).	
3	Type of ceiling and lights?	
4	*1. mas kasih ruang yang buat orang gak harus sign up dulu soalnya kadang2 orang males sign up* *2. mas kameranya kaya game2 fps dong bisa 360 derajat biar dia bisa nunduk kebawah hehehe* *3. kayaknya movement player pake scrollbar keren jadi user sedikit gak ribet* *4. bagus sama konsepnya mas*	1. There should be an option to allow a participant to participate without signing-up 2. A participant wished that the camera can do the 360-degree movement (note: 360-degree movement is doable) 3. Suggesting that the player's movement to use scroll bar instead of a keyboard. 4. Nice concept.
5	Pengaturan camera,pengaturan warna yang kurang, saya pengen warnanya pada tembok bisa di mix, dan saya pengen berikan effect pada ruangan saat terang dan gelap	More camera controlling, more options for colour, the participant would like to have the ability to combine different colours and show the (lighting) effect at bright (day) and dark (night).
6	Error on the movement keyboard (uncontrolled, moving without my instructions)	
7	Make more variation on the design, the colour just use the pallet because not all people know colour theory	

Appendix E: First Stage Results

E.1. Usability Test

Reliability Statistic

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.871	0.873	7

Item-Total Statistics Table

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Q01	29.5455	42.600	.677	.521	.849
Q02	29.9091	41.183	.733	.593	.841
Q03	29.6198	44.104	.708	.580	.846
Q04	30.1653	44.956	.699	.528	.848
Q05	30.0909	45.967	.574	.429	.862
Q06	30.5620	44.948	.544	.343	.868
Q07	29.9587	44.823	.622	.404	.856

Item Statistic

	Mean	Std. Deviation	N
Q01	5.43	1.55	121
Q02	5.07	1.60	121
Q03	5.36	1.36	121
Q04	4.81	1.29	121
Q05	4.88	1.39	121
Q06	4.41	1.56	121
Q07	5.02	1.43	121

Responses Distribution

	Disagreed	Undecided	Agreed
Q1	13	17	91
	10.74%	14.05%	75.21%
Q2	17	23	81
	14.05%	19.01%	66.94%
Q3	7	26	88
	5.79%	21.49%	72.73%
Q4	16	32	73
	13.22%	26.45%	60.33%
Q5	16	29	76
	13.22%	23.97%	62.81%
Q6	31	32	58
	25.62%	26.45%	47.93%
Q7	8	39	74
	6.61%	32.23%	61.16%

E.2. Preferences Data Analysis

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.221	.242	8

Item-Total Statistics Table

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
CT	102.3656	917.152	-.041	.078	.230
WT	102.4194	924.666	-.148	.082	.236
FLX	96.0591	912.683	-.040	.182	.236
FLZ	95.1935	901.368	.028	.232	.222
CH	101.6344	913.076	.014	.237	.225
CC	82.0860	558.111	.122	.048	.174
CF	76.0645	510.050	.183	.066	.094
CW	87.6828	595.688	.215	.071	.071

Correlation Between Variables

		CT	WT	FLX	FLZ	CH	CC	CF	CW
CT	Correlation Coefficient	1.000	.169*	0.106	-0.063	0.078	-0.080	0.039	-0.054
	Sig. (2-tailed)		0.021	0.148	0.393	0.289	0.279	0.596	0.463
	N	186	186	186	186	186	186	186	186
WT	Correlation Coefficient	.169*	1.000	0.010	-0.059	.186*	-0.082	-0.122	-0.066
	Sig. (2-tailed)	0.021		0.891	0.424	0.011	0.263	0.097	0.371
	N	186	186	186	186	186	186	186	186
FLX	Correlation Coefficient	0.106	0.010	1.000	.293**	.298**	-0.094	-0.048	-0.058
	Sig. (2-tailed)	0.148	0.891		0.000	0.000	0.202	0.516	0.434
	N	186	186	186	186	186	186	186	186
FLZ	Correlation Coefficient	-0.063	-0.059	.293**	1.000	.413**	-0.062	0.040	-0.074
	Sig. (2-tailed)	0.393	0.424	0.000		0.000	0.398	0.587	0.312
	N	186	186	186	186	186	186	186	186
CH	Correlation Coefficient	0.078	.186*	.298**	.413**	1.000	-0.086	-0.059	-0.070
	Sig. (2-tailed)	0.289	0.011	0.000	0.000		0.241	0.422	0.342
	N	186	186	186	186	186	186	186	186
CC	Correlation Coefficient	-0.080	-0.082	-0.094	-0.062	-0.086	1.000	0.045	0.129
	Sig. (2-tailed)	0.279	0.263	0.202	0.398	0.241		0.538	0.080
	N	186	186	186	186	186	186	186	186
CF	Correlation Coefficient	0.039	-0.122	-0.048	0.040	-0.059	0.045	1.000	.181*
	Sig. (2-tailed)	0.596	0.097	0.516	0.587	0.422	0.538		0.014
	N	186	186	186	186	186	186	186	186
CW	Correlation Coefficient	-0.054	-0.066	-0.058	-0.074	-0.070	0.129	.181*	1.000
	Sig. (2-tailed)	0.463	0.371	0.434	0.312	0.342	0.080	0.014	
	N	186	186	186	186	186	186	186	186
*. Correlation is significant at the 0.05 level (2-tailed).									
**. Correlation is significant at the 0.01 level (2-tailed).									

CT = Ceiling Type
WT = Windows Type
FLX = Floor Length X
FLZ = Floor Length Z
CH = Ceiling Height
CC = Colour Ceiling
CF = Colour Floor
CW = Colour Wall

Descriptive Statistics

Table 13. Descriptive Statistics of The Preferences Data

		CType	WType	FlrLengthX	FlrLengthZ	CeilingHeight	ColCeiling	ColFloor	ColWall
N	Valid	186	186	186	186	186	186	186	186
	Missing	0	0	0	0	0	0	0	0
Mean		3.85	3.80	10.16	11.02	4.58	24.13	30.15	18.53
Median		4	4	10	10	4	19.5	37	15
Mode		3	3	8	8	4	48	48	.00[a]
Std. Deviation		1.51	1.14	3.33	3.03	1.23	16.25	16.43	13.39
Variance		2.27	1.31	11.12	9.21	1.52	264.21	269.84	179.42
Skewness		-0.16	-0.01	0.35	0.35	1.07	0.26	-0.52	0.63
Std. Error of Skewness		0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Minimum		1	1	3	5	2	0	0	0
Maximum		6	6	16	16	8	48	48	48

a. Multiple modes exist. The smallest value is shown

E.3. Surfaces Colour Preferences

Wall Colour Preference

Rank	Name	Code	Frequency	%
1	Duck egg	13	14	8.14
2	Blue	14	11	6.40
3	White	48	10	5.81
4	Sky	15	9	5.23
5	Aqua	16	8	4.65
	Lemon	27	8	4.65
6	Breeze	7	7	4.07
	Navy	17	7	4.07
7	Mist	8	6	3.49
8	Buttercup	3	5	2.91
	Cream	6	5	2.91
	Green	26	5	2.91
	Pistachio	28	5	2.91
	Yellow	29	5	2.91
9	Grass	1	4	2.33
	Latte	4	4	2.33
	Lilac	19	4	2.33
	Lime	39	4	2.33
10	Apple	2	3	1.74
	Blossom	11	3	1.74
	Dusy Pink	12	3	1.74
	Musk	22	3	1.74
	Spearmint	24	3	1.74
	Turquoise	25	3	1.74
11	Haze	5	2	1.16
	Mint	9	2	1.16
	Ocean	10	2	1.16
	Orange	18	2	1.16
	Peach	20	2	1.16
	Petal	23	2	1.16
	Poppy	30	2	1.16
	Purple	31	2	1.16
	Red	35	2	1.16
	Rose	36	2	1.16
	Rouge	37	2	1.16
	Slate	38	2	1.16
	Vanilla	45	2	1.16
12	Almond	21	1	0.58
	Apricot	32	1	0.58
	Black	34	1	0.58
	Brown	40	1	0.58
	Charcoal	42	1	0.58
	Pink	46	1	0.58
	Tulip	47	1	0.58
13	Beige	33	0	0.00
	Choc	41	0	0.00
	Coral	43	0	0.00
	Grey	44	0	0.00

*custom colours are not included

Floor Colours Preference

Rank	Name	Code	Frequency	%
1	White	48	19	10.56
2	Charcoal	46	18	10.00
3	Black	47	12	6.67
4	Beige	41	8	4.44
5	Slate	45	7	3.89
6	Buttercup	17	6	3.33
	Latte	27	6	3.33
	Lemon	28	6	3.33
	Navy	38	6	3.33
	Vanilla	39	6	3.33
7	Breeze	5	5	2.78
	Grey	7	5	2.78
	Mint	44	5	2.78
8	Almond	1	4	2.22
	Apricot	32	4	2.22
	Choc	36	4	2.22
	Grass	40	4	2.22
	Red	43	4	2.22
9	Apple	2	3	1.67
	Aqua	6	3	1.67
	Blossom	8	3	1.67
	Blue	10	3	1.67
	Duck egg	13	3	1.67
	Mist	14	3	1.67
	Ocean	15	3	1.67
	Pistachio	16	3	1.67
	Purple	18	3	1.67
	Rouge	25	3	1.67
	Sky	37	3	1.67
10	Brown	3	2	1.11
	Green	4	2	1.11
	Lime	22	2	1.11
	Musk	30	2	1.11
	Orange	42	2	1.11
11	Cream	11	1	0.56
	Dusy Pink	12	1	0.56
	Petal	20	1	0.56
	Poppy	23	1	0.56
	Rose	24	1	0.56
	Spearmint	26	1	0.56
	Tulip	34	1	0.56
	Turquoise	35	1	0.56
12	Coral	9	0	0.00
	Haze	19	0	0.00
	Lilac	21	0	0.00
	Peach	29	0	0.00
	Pink	31	0	0.00
	Yellow	33	0	0.00

Ceiling Colours Preference

Rank	Name	Code	Frequency	%
1	White	48	28	15.64
2	Blue	14	14	7.82
3	Breeze	7	10	5.59
4	Duck egg	13	8	4.47
5	Black	3	6	3.35
	Green	4	6	3.35
	Lime	10	6	3.35
	Ocean	47	6	3.35
6	Aqua	16	5	2.79
	Cream	17	5	2.79
	Grey	19	5	2.79
	Lemon	26	5	2.79
	Lilac	27	5	2.79
	Navy	44	5	2.79
7	Rose	20	4	2.23
	Vanilla	38	4	2.23
8	Apple	2	3	1.68
	Beige	15	3	1.68
	Charcoal	18	3	1.68
	Dusy Pink	24	3	1.68
	Latte	29	3	1.68
	Purple	39	3	1.68
	Sky	41	3	1.68
	Yellow	46	3	1.68
9	Brown	6	2	1.12
	Buttercup	8	2	1.12
	Haze	9	2	1.12
	Mist	11	2	1.12
	Orange	12	2	1.12
	Peach	21	2	1.12
	Pink	28	2	1.12
	Pistachio	30	2	1.12
	Spearmint	31	2	1.12
	Turquoise	42	2	1.12
10	Almond	1	1	0.56
	Apricot	5	1	0.56
	Blossom	22	1	0.56
	Choc	23	1	0.56
	Coral	25	1	0.56
	Grass	32	1	0.56
	Mint	33	1	0.56
	Musk	34	1	0.56
	Petal	35	1	0.56
	Poppy	37	1	0.56
	Rouge	40	1	0.56
	Slate	43	1	0.56
	Tulip	45	1	0.56
11	Red	36	0	0

E.4. Spatial Dimensions Preferences

Floor Length X Preference

Rank	Range (m)	Frequency	%
1	8 - 8.9	36	19.35
2	16	26	13.98
3	11 - 11.9	23	12.37
4	9 - 9.9	20	10.75
5	10 - 10.9	19	10.22
6	7 - 7.9	14	7.53
7	6 - 6.9	10	5.38
	13 - 13.9	10	5.38
8	14 - 14.9	8	4.30
9	12 - 12.9	7	3.76
10	5 - 5.9	6	3.23
11	4 - 4.9	3	1.61
12	3 - 3.9	2	1.08
	15 - 15.9	2	1.08
13	2 - 2.9	0	0.00

Floor Length Z Preference

Rank	Range (m)	Frequency	%
1	8 - 8.9	32	17.20
2	16	29	15.59
3	9 - 9.9	27	14.52
4	10 - 10.9	23	12.37
5	12 - 12.9	21	11.29
6	11 - 11.9	14	7.53
7	13 - 13.9	12	6.45
8	7 - 7.9	9	4.84
	15 - 15.9	9	4.84
9	14 - 14.9	5	2.69
10	5 - 5.9	3	1.61
11	6 - 6.9	2	1.08
12	2 - 2.9	0	0.00
	3 - 3.9	0	0.00
	4 - 4.9	0	0.00

Ceiling Height Preference

Rank	Range (m)	Frequency	%
1	4 - 4.9	92	49.46
2	5 - 5.9	45	24.19
3	3 - 3.9	15	8.06
4	6 - 6.9	13	6.99
5	8	9	4.84
6	7 - 7.9	8	4.30
7	2 - 2.9	4	2.15

E.5. Elements Style Preferences

Window Styles Preference

Rank	Type	Freq	%
1	3	67	36.02
2	4	53	28.49
3	5	37	19.89
4	6	14	7.53
5	2	9	4.84
6	1	6	3.23

Ceiling Styles Preference

Rank	Type	Freq	%
1	3	44	23.66
2	5	39	20.97
3	4	34	18.28
4	6	32	17.20
5	2	24	12.90
6	1	13	6.99

E.6. Group Preference

Gender-based - Correlation Test (Female/Male)

			Female	Male
Spearman's rho	Female	Correlation Coefficient	1.000	.571**
		Sig. (2-tailed)	.	.000
		N	193	193
	Male	Correlation Coefficient	.571**	1.000
		Sig. (2-tailed)	.000	.
		N	193	193
**. Correlation is significant at the 0.01 level (2-tailed).				

Location-based - Correlation Test (Indonesia/United Kindom/Japan)

			IND	UK	JPN
Spearman's rho	IND	Correlation Coefficient	1	.570**	.394**
		Sig. (2-tailed)	.	0	0
		N	193	193	193
	UK	Correlation Coefficient	.570**	1	.400**
		Sig. (2-tailed)	0	.	0
		N	193	193	193
	JPN	Correlation Coefficient	.394**	.400**	1
		Sig. (2-tailed)	0	0	.
		N	193	193	193
**. Correlation is significant at the 0.01 level (2-tailed).					

E.7. Comments and Feedbacks

	Comments and Feedbacks	Issues
1	Make some texture choice.	Texture
2	So far, I'd like to try this system	-
3	Need more option about the colour scheme for wall with textures maybe	Texture
4	Add more colour scheme for each wall would be more fun... I think :)	Individual colour to each wall
5	Should be more flexible for ceiling adjustment related to the space adjustment. It would much interesting if i could change (more) on the window shape	Ceiling Window's Style
6	*- Pilihan warna kurang banyak* *- ditambahkan tekstur material*	Colour - More Texture
7	Give a more optional alternative to give me more expression in the room	More options
8	Limited choices of the spatial elements.	Spatial element
9	Lighting	Lighting
10	1.The instruction and the purpose of this tool from the author and the c 1. The purpose and contribution of this research should be clearer. 2. Each page should be elaborated for the objective of each experiment. Ion	Research method
11	Difficult to use as not enough instruction provided. It is too difficult to control this device in order to view the overall perception from each elevation of the room. I'd suggest providing more alternatives to observer's positions focusing on human eye level not from only one position with various viewing direction like this. However, good effort. I believe that it can be improved much better adding more complicated functions. Good luck with your research. I'm looking forward to using it.	Navigation Information Viewpoint
12	For material colour choice, is that possible to choose texture rather than just colour? It will have more reality in that way.	Texture
13	More control on view, more colour scheme, more types or flexibility of ceiling and window shapes and characteristics	Colour – More, Scheme
14	Warna yang dipilih kadang jadi berubah ketika diaplikasikan.	Colour - issue
15	I think it's better for develop with "real programmer"	
16	Improve light effect	Lighting
17	So easy to use this system	-
18	It would be great if I can move the furniture and adjust the window, floor level and ceiling design. Also, there are no material preferences in this system.	Material
19	The scheme already has the feel of study or learning space (i.e. The furniture of studying are already been provided; tables, chairs). Technically the application is working very well, no loading or error. Perhaps could consider what to do with the other walls given on the scheme (for instance what to do with them; should they be just blank/plain or have openings as well). Perhaps could also consider adding more types of openings/windows. Overall; the application works so amazingly :)	
20	Ganbatte! :p	-
21	*1. Mas sepertinya brighnes lightnya tambahin supaya lebih cerah.*	Lighting
22	*Letak jendela bisa engga di pasang di setiap tembok dan pilihan warnany kurang banyak*	Colour
23	Colour adjustment is quite hard	Colour
24	A 3-D rotation would be nice	Navigation
25	Pilihan warna agak sulit menentukan karena antar blok warna kurang tegas. Warna blok dengan warna hasil juga terkesan berbeda karena pengaruh pencahayaan.	Colour - Appearance
26	Bigger review box (this)	-
27	Colour kalau bisa pake RGB biar lebih variatif. Untuk kemudahan pas awal2 bikin systemnya gak bingungin sih, trus informationnya kurang jelas. Tutorialnya harus lebih di tekankan pas awl2 make. Spacious nes... Gw ga suka meja kursinya. Gw ngerasa ga ngerepresent and agak ganggu, terutama ga di kasih collision jd gw bingung whats the point it is there. Preferences for	Generally confusing, Unclear information, Did not like the furniture, windows,

	windows and ceiling type itu tergantung yah, kalau misalnya mao untuk artist di kasih beginian pasti ga setuju karena ga enak kalau.	ceiling
28	....Prefer the selection colour can use the arrow to choose, and change the instant	Prefer to click – change than a slider
29	Texture as material	Texture
30	More type of ceiling and window please and make sure about colour to be easier than this.	Element's Style Colour
31	The application of colour can't match well with my expectation.	Colour
32	Cannot apply bright and soft colour well	Colour
33	Nope	-
34	Jika ada Kombinasi warna sebagai contoh akan lebih baik, tidak semua orang punya pemilihan pilihan kombinasi warna yang tepat. Kadang dengan melihat kombinasi warna yang sudah tersedia menjadi ada bayangan untuk mendapat kombinasi gambar yang baik.	
35	Opsi yang banyak membuat desainer menjadi lebih bebas untuk mendesain	More features
36	More colours please	Colour
37	Maybe you could put 2 more windows type	
38	I love wide windows	
39	More colours	Colour
40	Can you add more thing to adjust	
41	Sometimes the colours in RGB slider doesn't match with the result	Colour
42	Kesulitan menyesuaikan warna lantainya	Colour
43	Pilihan warnanya kurang banyak	Colour
44	More colours, please	Colour
45	Use CYMK please to give more choice at the colour	Colour
46	More pattern of the floor	
47	Firstly, the layout of learning spaces, such as the desk layout, do not include other alternatives. It could be important. Secondly, if colouring parts have a limited number of colours, for instance, 5 or 6 colours, it might be better to identify the user's preference.	Furniture layout
48	....Provide the materials to select (i.e. Flooring)	Material
49	More colours + another lighting type	• Colour • Lighting
50	At times, I could not see the mouse adjust the sliders! Had to gradually hover of them to find them!	Navigation
51	Room shape perhaps? Wallpaper?	Room shape
52	More options could be provided in terms of window and ceiling types	Element's Style
53	Colour: wanted a darker blue for the carpet. Ceiling/windows, there are certainly more types you could include but maybe more traditional varieties are needed; although a good range of modern designs. Will you be contacted via email? Can't fit it into the box below	Colour
54	The fact that the furniture cannot be adjusted to colour, as well as the flat colours being quite unrealistic thus make it hard to judge which colours should be used.	Colour
55	And tilt function for the navigation camera	Navigation
56	Could the shape of the room be allowed to be more complex? This could allow desks and chairs to be positioned around corners with more seclusion for the user, potentially creating a better working environment.	
57	Amazing!!!!!! I loved it!	-
58	It might help to change the instruction about clicking NEXT to press ENTER because I couldn't see the NEXT button anywhere but pressing ENTER worked. Also, the box to enter your email below is too short to fit my whole address in."	Interface – issue
59	The type of window and ceiling could more	Element Styles - More
60	Zoom in and out button. This would be useful for selecting the size of the space. Personally, I selected a width, height and length which I could see on my screen. Others may possibly do the same	View limitation
61	More time to answer will be better	

62	If you could include different materials and texture in your pallets to give the users an opportunity to experiences the real feeling of different materials and textures	Texture / material
63	..more colours options,lighting options,tiles options,Plants and furniture options,wall pictures..	• Colour • Lighting • Tiles • Plants • Furniture • Wall hanging

Appendix F. Design and Non-Design Comparison

F.1. Usability-test Correlation

			Non-Design	Design
Spearman's rho	Non-Design	Correlation Coefficient	1.000	.786*
		Sig. (2-tailed)	.	.036
		N	7	7
	Design	Correlation Coefficient	.786*	1.000
		Sig. (2-tailed)	.036	.
		N	7	7
*. Correlation is significant at the 0.05 level (2-tailed).				

F.2. Preferences Comparison

Wall Colour - Preferences Comparison

Non-Design			Design		
Col. Name	Freq.	%	%	Freq.	Col. Name
Duck egg	12	8.33	9.09	4	Blue**
White	9	6.25	6.82	3	Cream
Sky	8	5.56	6.82	3	Green
Aqua	7	4.86	6.82	3	Navy
Blue	7	4.86	4.55	2	Breeze
Lemon	6	4.17	4.55	2	Duck egg
Breeze	5	3.47	4.55	2	Lemon
Buttercup	5	3.47	4.55	2	Orange
Mist	5	3.47	4.55	2	Red
Grass	4	2.78	4.55	2	Turquoise
Latte	4	2.78	4.55	2	Yellow
Lime	4	2.78	2.27	1	Almond
Navy	4	2.78	2.27	1	Apple
Pistachio	4	2.78	2.27	1	Aqua
Dusy Pink	3	2.08	2.27	1	Blossom
Lilac	3	2.08	2.27	1	Lilac
Musk	3	2.08	2.27	1	Mint
Spearmint	3	2.08	2.27	1	Mist
Yellow	3	2.08	2.27	1	Peach
Apple	2	1.39	2.27	1	Pistachio
Blossom	2	1.39	2.27	1	Purple
Cream	2	1.39	2.27	1	Rose
Green	2	1.39	2.27	1	Sky
Haze	2	1.39	2.27	1	Slate
Ocean	2	1.39	2.27	1	White
Petal	2	1.39	0.00	0	Apricot
Poppy	2	1.39	0.00	0	Beige
Rouge	2	1.39	0.00	0	Black
Vanilla	2	1.39	0.00	0	Brown
Apricot	1	0.69	0.00	0	Buttercup
Black	1	0.69	0.00	0	Charcoal
Brown	1	0.69	0.00	0	Choc
Charcoal	1	0.69	0.00	0	Coral
Mint	1	0.69	0.00	0	Dusy Pink
Peach	1	0.69	0.00	0	Grass
Pink	1	0.69	0.00	0	Grey
Purple	1	0.69	0.00	0	Haze
Rose	1	0.69	0.00	0	Latte
Slate	1	0.69	0.00	0	Lime
Tulip	1	0.69	0.00	0	Musk
Turquoise	1	0.69	0.00	0	Ocean
Almond	0	0.00	0.00	0	Petal
Beige	0	0.00	0.00	0	Pink
Choc	0	0.00	0.00	0	Poppy
Coral	0	0.00	0.00	0	Rouge
Grey	0	0.00	0.00	0	Spearmint
Orange	0	0.00	0.00	0	Tulip
Red	0	0.00	0.00	0	Vanilla
** Duck egg and Blue are nearly identical colours					
*** The table excludes custom colours					

Ceiling Colours - Preferences Comparison

Non-Design			Design		
Col. Name	Freq.	%	%	Freq.	Col. Name
White	18	12.50	22.73	10	White
Blue	13	9.03	6.82	3	Duck egg
Breeze	8	5.56	6.82	3	Lemon
Green	6	4.17	4.55	2	Black
Aqua	5	3.47	4.55	2	Breeze
Duck egg	5	3.47	4.55	2	Grey
Lime	5	3.47	4.55	2	Mist
Black	4	2.78	4.55	2	Ocean
Cream	4	2.78	4.55	2	Purple
Lilac	4	2.78	4.55	2	Vanilla
Navy	4	2.78	2.27	1	Apple
Ocean	4	2.78	2.27	1	Beige
Dusy Pink	3	2.08	2.27	1	Blue
Grey	3	2.08	2.27	1	Brown
Latte	3	2.08	2.27	1	Charcoal
Rose	3	2.08	2.27	1	Cream
Yellow	3	2.08	2.27	1	Lilac
Apple	2	1.39	2.27	1	Lime
Beige	2	1.39	2.27	1	Musk
Buttercup	2	1.39	2.27	1	Navy
Charcoal	2	1.39	2.27	1	Peach
Haze	2	1.39	2.27	1	Pistachio
Lemon	2	1.39	2.27	1	Rose
Orange	2	1.39	2.27	1	Sky
Pink	2	1.39	0.00	0	Almond
Sky	2	1.39	0.00	0	Apricot
Spearmint	2	1.39	0.00	0	Aqua
Turquoise	2	1.39	0.00	0	Blossom
Vanilla	2	1.39	0.00	0	Buttercup
Almond	1	0.69	0.00	0	Choc
Apricot	1	0.69	0.00	0	Coral
Blossom	1	0.69	0.00	0	Dusy Pink
Brown	1	0.69	0.00	0	Grass
Choc	1	0.69	0.00	0	Green
Coral	1	0.69	0.00	0	Haze
Grass	1	0.69	0.00	0	Latte
Mint	1	0.69	0.00	0	Mint
Peach	1	0.69	0.00	0	Orange
Petal	1	0.69	0.00	0	Petal
Pistachio	1	0.69	0.00	0	Pink
Poppy	1	0.69	0.00	0	Poppy
Purple	1	0.69	0.00	0	Red
Rouge	1	0.69	0.00	0	Rouge
Slate	1	0.69	0.00	0	Slate
Tulip	1	0.69	0.00	0	Spearmint
Mist	0	0.00	0.00	0	Tulip
Musk	0	0.00	0.00	0	Turquoise
Red	0	0.00	0.00	0	Yellow
*** The table excludes custom colours					

Floor Colours - Preferences Comparison

Non-Design			Design		
Col. Name	Freq.	%	%	Freq.	Col. Name
White	14	9.72	15.91	7	Charcoal
Charcoal	11	7.64	11.36	5	Black
Beige	7	4.86	11.36	5	White
Black	7	4.86	9.09	4	Navy
Slate	6	4.17	6.82	3	Choc
Buttercup	5	3.47	4.55	2	Grey
Vanilla	5	3.47	4.55	2	Latte
Almond	4	2.78	4.55	2	Lemon
Apricot	4	2.78	2.27	1	Beige
Breeze	4	2.78	2.27	1	Breeze
Grass	4	2.78	2.27	1	Brown
Latte	4	2.78	2.27	1	Buttercup
Lemon	4	2.78	2.27	1	Green
Mint	4	2.78	2.27	1	Lime
Red	4	2.78	2.27	1	Mint
Apple	3	2.08	2.27	1	Musk
Aqua	3	2.08	2.27	1	Orange
Blossom	3	2.08	2.27	1	Pistachio
Blue	3	2.08	2.27	1	Purple
Duck egg	3	2.08	2.27	1	Slate
Grey	3	2.08	2.27	1	Vanilla
Mist	3	2.08	0.00	0	Almond
Ocean	3	2.08	0.00	0	Apple
Rouge	3	2.08	0.00	0	Apricot
Sky	3	2.08	0.00	0	Aqua
Navy	2	1.39	0.00	0	Blossom
Pistachio	2	1.39	0.00	0	Blue
Purple	2	1.39	0.00	0	Coral
Brown	1	0.69	0.00	0	Cream
Choc	1	0.69	0.00	0	Duck egg
Cream	1	0.69	0.00	0	Dusy Pink
Dusy Pink	1	0.69	0.00	0	Grass
Green	1	0.69	0.00	0	Haze
Lime	1	0.69	0.00	0	Lilac
Musk	1	0.69	0.00	0	Mist
Orange	1	0.69	0.00	0	Ocean
Petal	1	0.69	0.00	0	Peach
Poppy	1	0.69	0.00	0	Petal
Rose	1	0.69	0.00	0	Pink
Spearmint	1	0.69	0.00	0	Poppy
Tulip	1	0.69	0.00	0	Red
Turquoise	1	0.69	0.00	0	Rose
Coral	0	0.00	0.00	0	Rouge
Haze	0	0.00	0.00	0	Sky
Lilac	0	0.00	0.00	0	Spearmint
Peach	0	0.00	0.00	0	Tulip
Pink	0	0.00	0.00	0	Turquoise
Yellow	0	0.00	0.00	0	Yellow
*** The table excludes custom colours					

Floor-length X - Preferences Comparison

Non-Design			Design		
Col. Name	Freq.	%	%	Freq.	Col. Name
8.00 - 8.95	23	15.97	29.55	13	8.00 - 8.95
16.00	21	14.58	13.64	6	11.00 - 11.95
11.00 - 11.95	17	11.81	11.36	5	16.00
10.00 - 10.95	15	10.42	11.36	5	9.00 - 9.95
9.00 - 9.95	15	10.42	9.09	4	10.00 - 10.95
7.00 - 7.95	12	8.33	6.82	3	5.00 - 5.95
13.00 - 13.95	9	6.25	4.55	2	6.00 - 6.95
6.00 - 6.95	8	5.56	4.55	2	7.00 - 7.95
14.00 - 14.95	7	4.86	2.27	1	12.00 - 12.95
12.00 - 12.95	6	4.17	2.27	1	13.00 - 13.95
5.00 - 5.95	3	2.08	2.27	1	14.00 - 14.95
15.00 - 15.95	2	1.39	2.27	1	4.00 - 4.95
3.00 - 3.95	2	1.39	0.00	0	15.00 - 15.95
4.00 - 4.95	2	1.39	0.00	0	2.00 - 2.95
2.00 - 2.95	0	0.00	0.00	0	3.00 - 3.95

Floor-Length Z - Preferences Comparison

Non-Design			Design		
Col. Name	Freq.	%	%	Freq.	Col. Name
8.00 - 8.95	28	19.44	22.73	10	16.00
9.00 - 9.95	20	13.89	15.91	7	9.00 - 9.95
16.00	19	13.19	13.64	6	10.00 - 10.95
12.00 - 12.95	18	12.50	11.36	5	13.00 - 13.95
10.00 - 10.95	17	11.81	9.09	4	8.00 - 8.95
11.00 - 11.95	11	7.64	6.82	3	11.00 - 11.95
7.00 - 7.95	8	5.56	6.82	3	12.00 - 12.95
13.00 - 13.95	7	4.86	4.55	2	14.00 - 14.95
15.00 - 15.95	7	4.86	4.55	2	15.00 - 15.95
14.00 - 14.95	3	2.08	2.27	1	5.00 - 5.95
5.00 - 5.95	2	1.39	2.27	1	7.00 - 7.95
6.00 - 6.95	2	1.39	0.00	0	2.00 - 2.95
2.00 - 2.95	0	0.00	0.00	0	3.00 - 3.95
3.00 - 3.95	0	0.00	0.00	0	4.00 - 4.95
4.00 - 4.95	0	0.00	0.00	0	6.00 - 6.95

Ceiling Heights - Preferences Comparison

Non-Design			Design		
Col. Name	Freq.	%	%	Freq.	Col. Name
4.00 - 4.95	69	47.92	52.27	23	4.00 - 4.95
5.00 - 5.95	33	22.92	27.27	12	5.00 - 5.95
6.00 - 6.95	12	8.33	11.36	5	3.00 - 3.95
3.00 - 3.95	10	6.94	4.55	2	8.00
8.00	7	4.86	2.27	1	6.00 - 6.95
7.00 - 7.95	7	4.86	2.27	1	7.00 - 7.95
2.00 - 2.95	4	2.78	0.00	0	2.00 - 2.95

Window Style - Preferences Comparison

Non-Design			Design		
Col. Name	Freq.	%	%	Freq.	Col. Name
WType03	48	33.33	43.18	19	WType03
WType04	42	29.17	25.00	11	WType04
WType05	30	20.83	15.91	7	WType05
WType06	12	8.33	6.82	3	WType02
WType02	6	4.17	4.55	2	WType01
WType01	4	2.78	4.55	2	WType06

Ceiling Styles - Preferences Comparison

Non-Design			Design		
Col. Name	Freq.	%	%	Freq.	Col. Name
CType03	36	25.00	27.27	12	CType05
CType04	31	21.53	20.45	9	CType06
CType05	27	18.75	18.18	8	CType02
CType06	23	15.97	18.18	8	CType03
CType02	16	11.11	9.09	4	CType01
CType01	9	6.25	6.82	3	CType04

F.3. Correlation Test

Wall Colour - Correlation Test

		Non-Design	Design
Non-Design	Correlation Coefficient	1	0.239
	Sig. (2-tailed)	.	0.102
	N	48	48
Design	Correlation Coefficient	0.239	1
	Sig. (2-tailed)	0.102	.
	N	48	48

Ceiling Colour - Correlation Test

		Non-Design	Design
Non-Design	Correlation Coefficient	1	.357*
	Sig. (2-tailed)	.	0.013
	N	48	48
Design	Correlation Coefficient	.357*	1
	Sig. (2-tailed)	0.013	.
	N	48	48
*. Correlation is significant at the 0.05 level (2-tailed).			

Floor Colour - Correlation Test

		Non-Design	Design
Non-Design	Correlation Coefficient	1	.432**
	Sig. (2-tailed)	.	0.002
	N	48	48
Design	Correlation Coefficient	.432**	1
	Sig. (2-tailed)	0.002	.
	N	48	48
**. Correlation is significant at the 0.01 level (2-tailed).			

Floor Length X - Correlation Test

		Non-Design	Design
Non-Design	Correlation Coefficient	1	.898**
	Sig. (2-tailed)	.	0
	N	15	15
Design	Correlation Coefficient	.898**	1
	Sig. (2-tailed)	0	.
	N	15	15
**. Correlation is significant at the 0.01 level (2-tailed).			

Floor Length Z - Correlation Test

		Non-Design	Design
Non-Design	Correlation Coefficient	1	.871**
	Sig. (2-tailed)	.	0
	N	15	15
Design	Correlation Coefficient	.871**	1
	Sig. (2-tailed)	0	.
	N	15	15
**. Correlation is significant at the 0.01 level (2-tailed).			

Ceiling Heights - Correlation Test

		Non-Design	Design
Non-Design	Correlation Coefficient	1	.827*
	Sig. (2-tailed)	.	0.022
	N	7	7
Design	Correlation Coefficient	.827*	1
	Sig. (2-tailed)	0.022	.
	N	7	7
*. Correlation is significant at the 0.05 level (2-tailed).			

Window Style - Correlation Test

		Non-Design	Design
Non-Design	Correlation Coefficient	1	.899*
	Sig. (2-tailed)	.	0.015
	N	6	6
Design	Correlation Coefficient	.899*	1
	Sig. (2-tailed)	0.015	.
	N	6	6
*. Correlation is significant at the 0.05 level (2-tailed).			

Ceiling Style - Correlation Test

		Non-Design	Design
Non-Design	Correlation Coefficient	1	0.029
	Sig. (2-tailed)	.	0.957
	N	6	6
Design	Correlation Coefficient	0.029	1
	Sig. (2-tailed)	0.957	.
	N	6	6

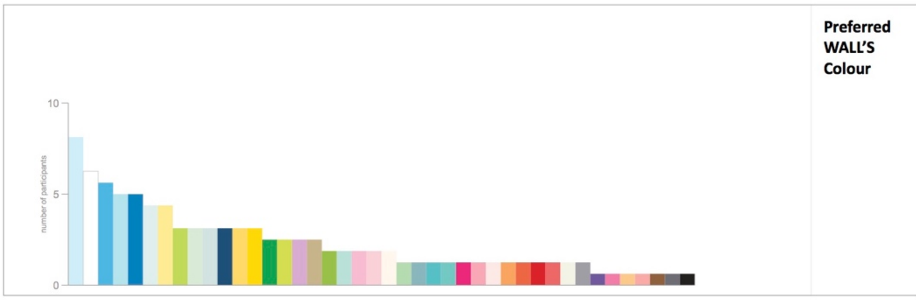
All Design Variables - Correlation Test

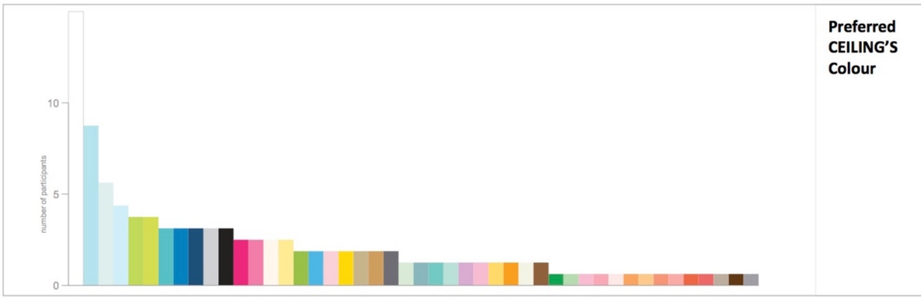
		NonDesign	Design
NonDesign	Correlation Coefficient	1.000	.614**
	Sig. (2-tailed)	.	.000
	N	193	193
Design	Correlation Coefficient	.614**	1.000
	Sig. (2-tailed)	.000	.
	N	193	193
**. Correlation is significant at the 0.01 level (2-tailed).			

Appendix G. Visual Preferences Data Document (PDF)

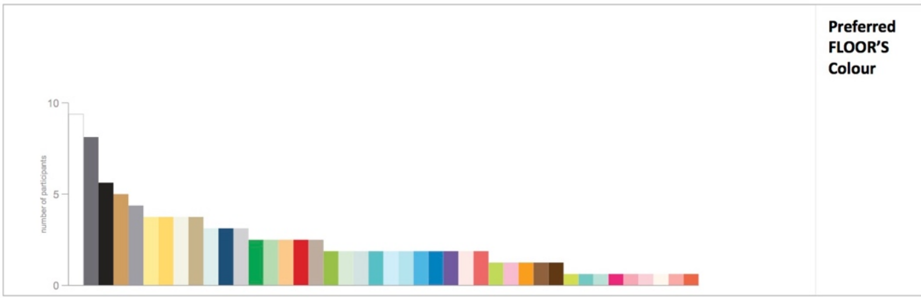
VISUAL PREFERENCES DATA for Communal Learning Spaces

Collected from 169 participants using web-based interactive virtual environment

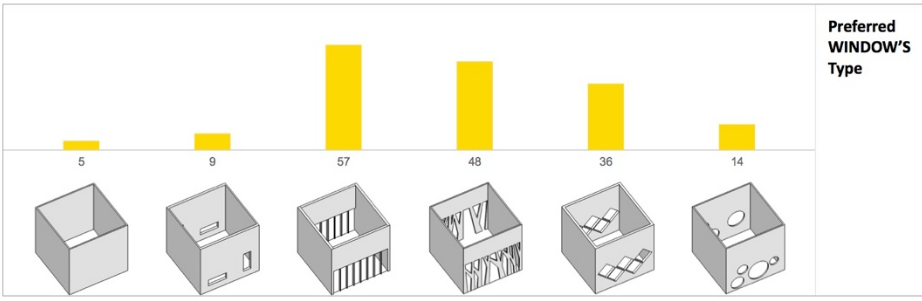




Preferred
CEILING'S
Colour
10
5
0
number of participants



Preferred
FLOOR'S
Colour
10
5
0
number of participants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48
36
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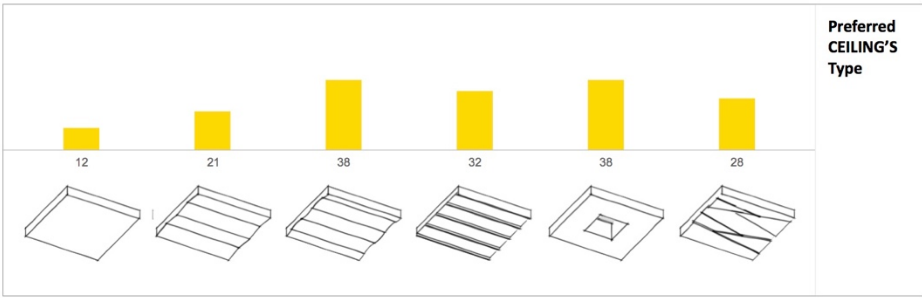
Preferred
CEILING'S
Type
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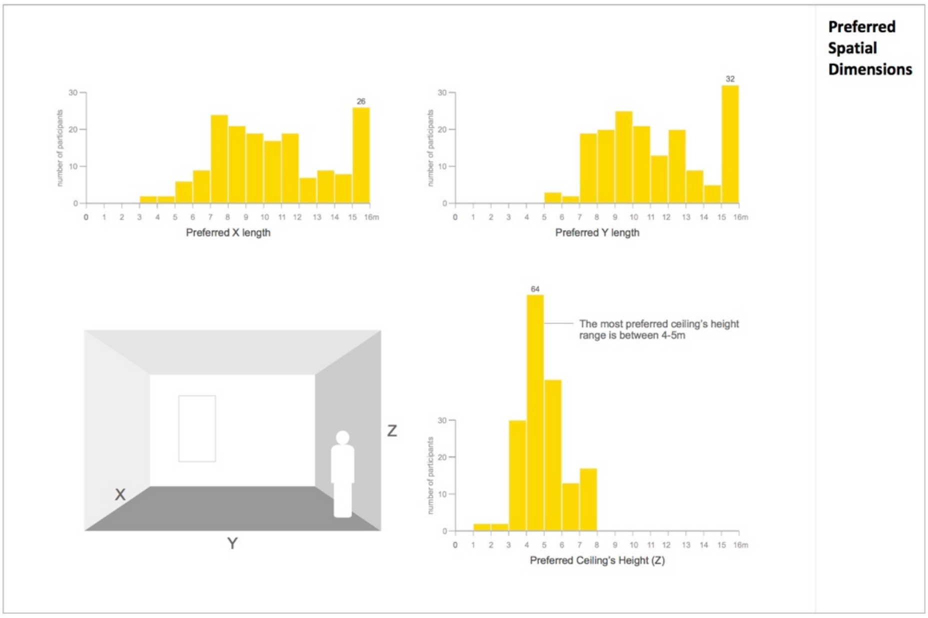
21
38
32
38
28



How confidence are the participants with their selections?

Appendix H. Second Stage Results

H.1. Questionnaire Analysis

Reliability Statistic

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.838	0.853	9

Item Statistic

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Q01	42.78	62.77	0.711	0.74	0.80
Q02	43.50	69.21	0.554	0.67	0.82
Q03	43.67	63.41	0.613	0.93	0.81
Q04	43.22	67.60	0.461	0.90	0.83
Q05	43.11	68.34	0.658	0.61	0.81
Q06	43.28	63.51	0.808	0.81	0.80
Q07	43.72	69.62	0.385	0.50	0.84
Q08	43.56	66.50	0.726	0.77	0.81
Q09	43.83	72.74	0.232	0.34	0.86

Responses Distribution

	Disagreed	Undecided	Agreed
Q1	1	1	16
	5.56%	5.56%	88.89%
Q2	1	3	14
	5.56%	16.67%	77.78%
Q3	3	1	14
	16.67%	5.56%	77.78%
Q4	2	2	14
	11.11%	11.11%	77.78%
Q5	0	4	14
	0.00%	22.22%	77.78%
Q6	1	3	14
	5.56%	16.67%	77.78%
Q7	2	3	13
	11.11%	16.67%	72.22%
Q8	1	5	12
	5.56%	27.78%	66.67%
Q9	3	6	9
	16.67%	33.33%	50.00%

H.2. Designer Responses

Designer D01

Designer D02

Designer D03

Designer D04

Designer D05

Designer D06

Designer D07

Designer D08

Designer D09

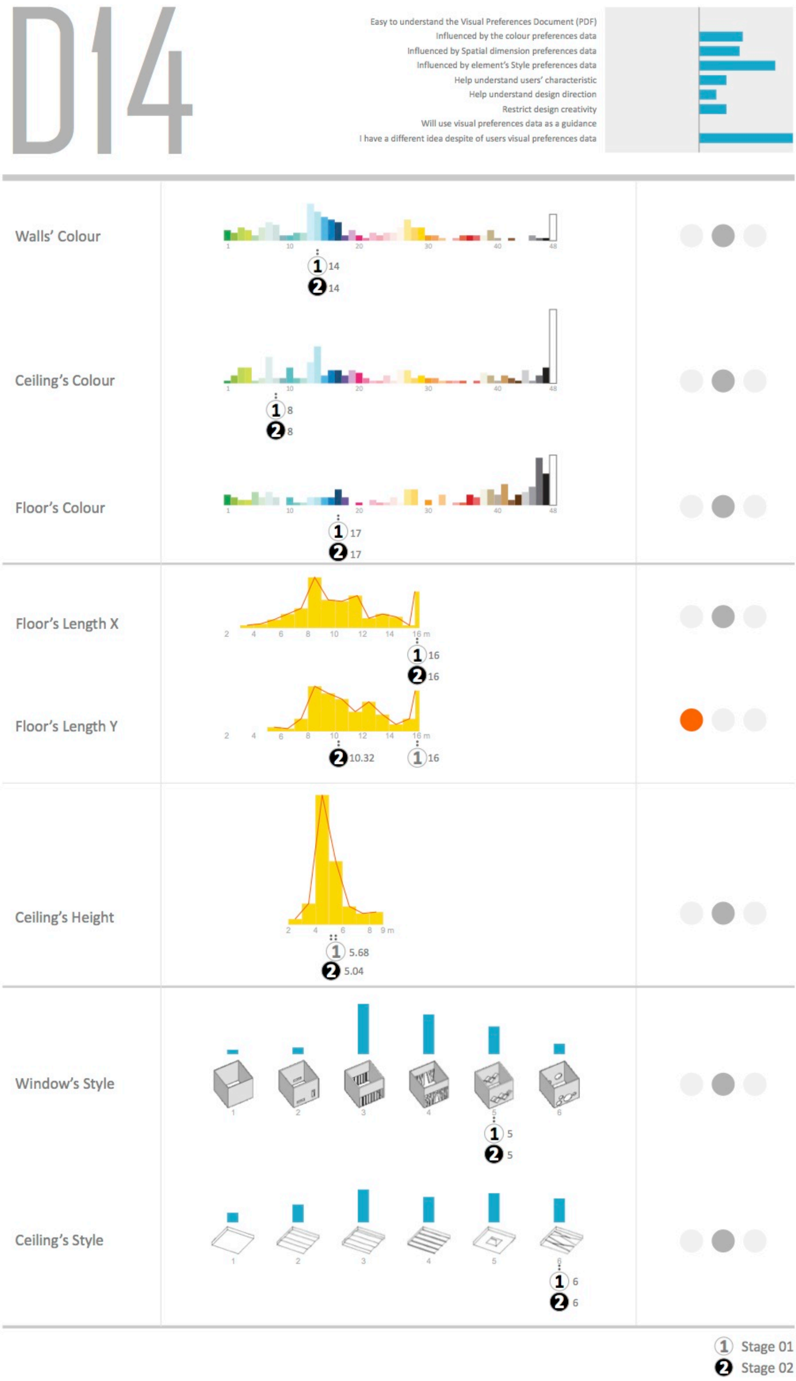
Designer D010

Designer D011

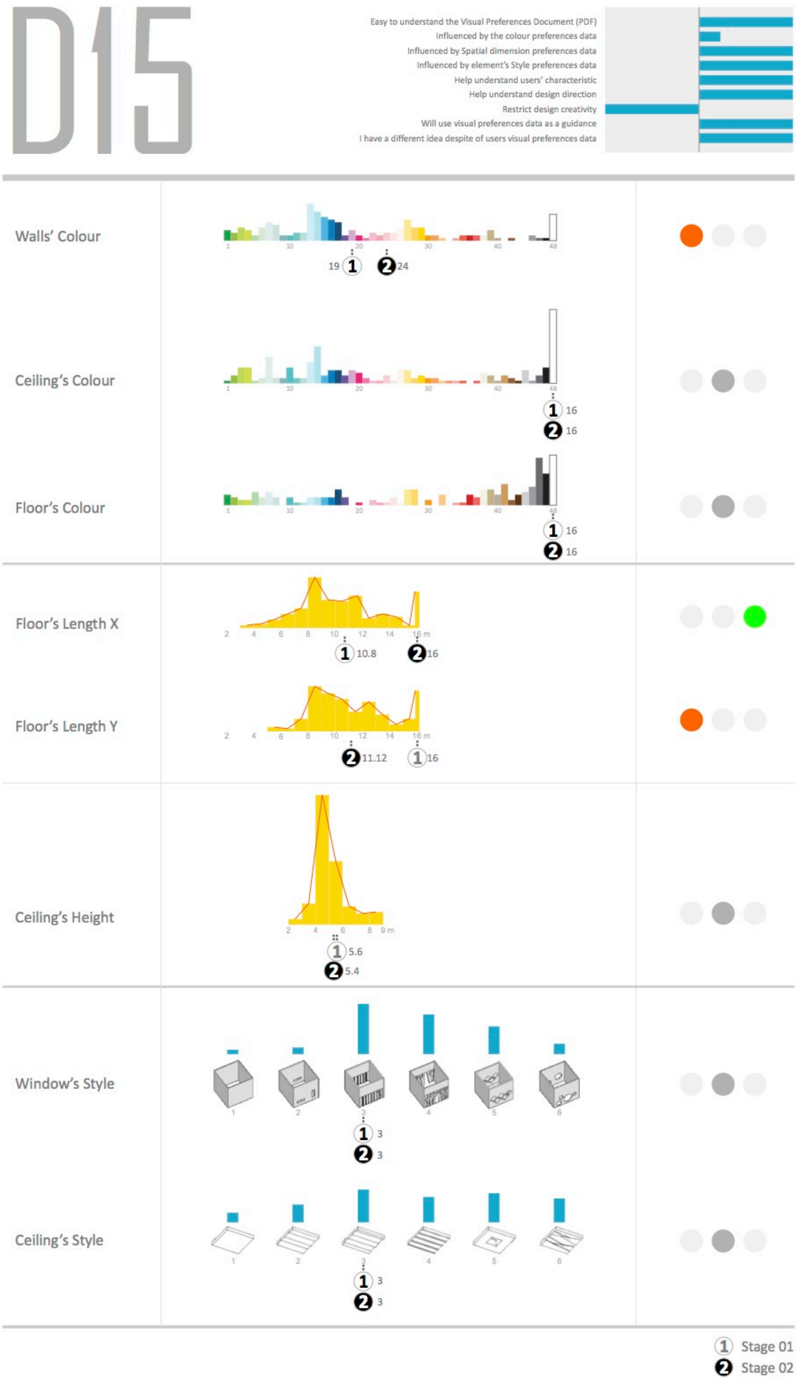
Designer D012

Designer D013

Designer D014

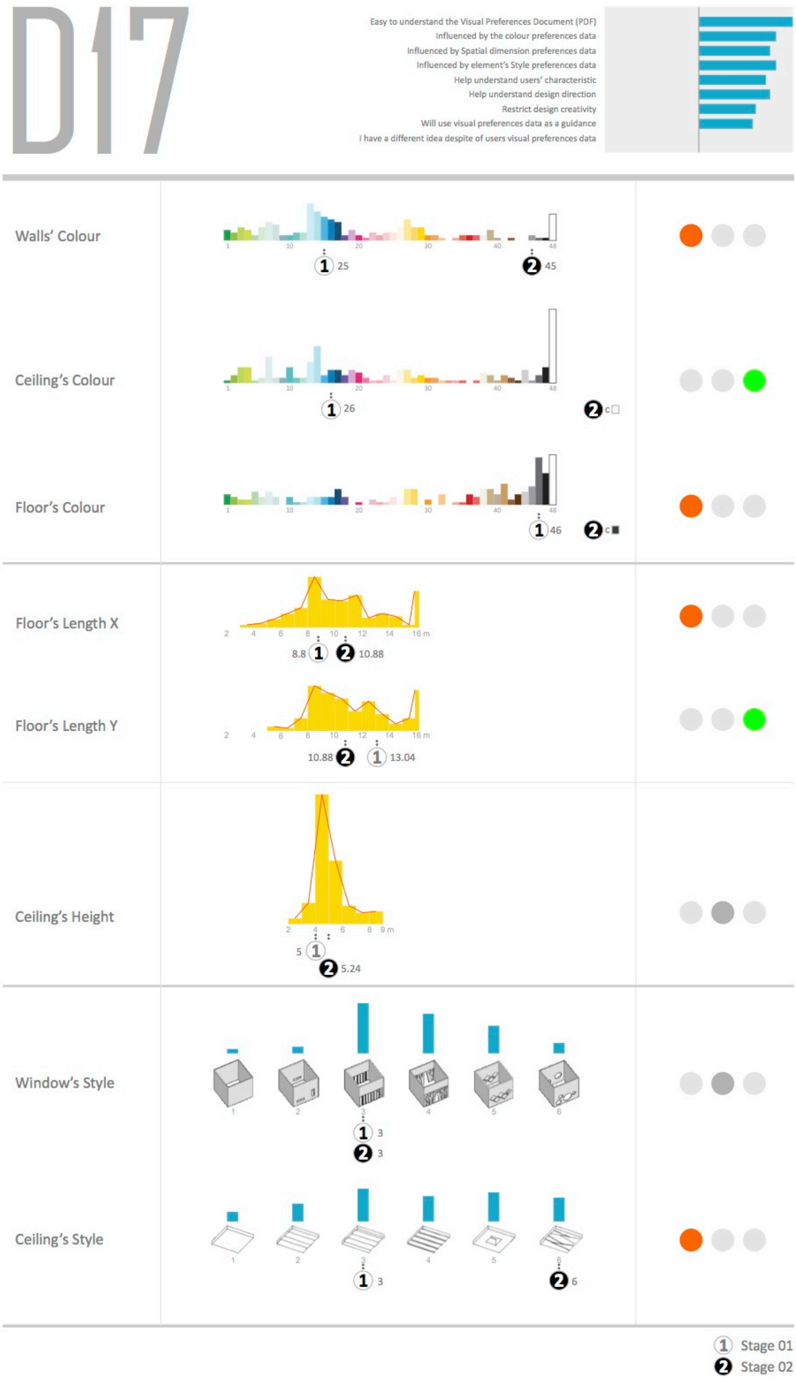


Designer D015



Designer D016

Designer D017



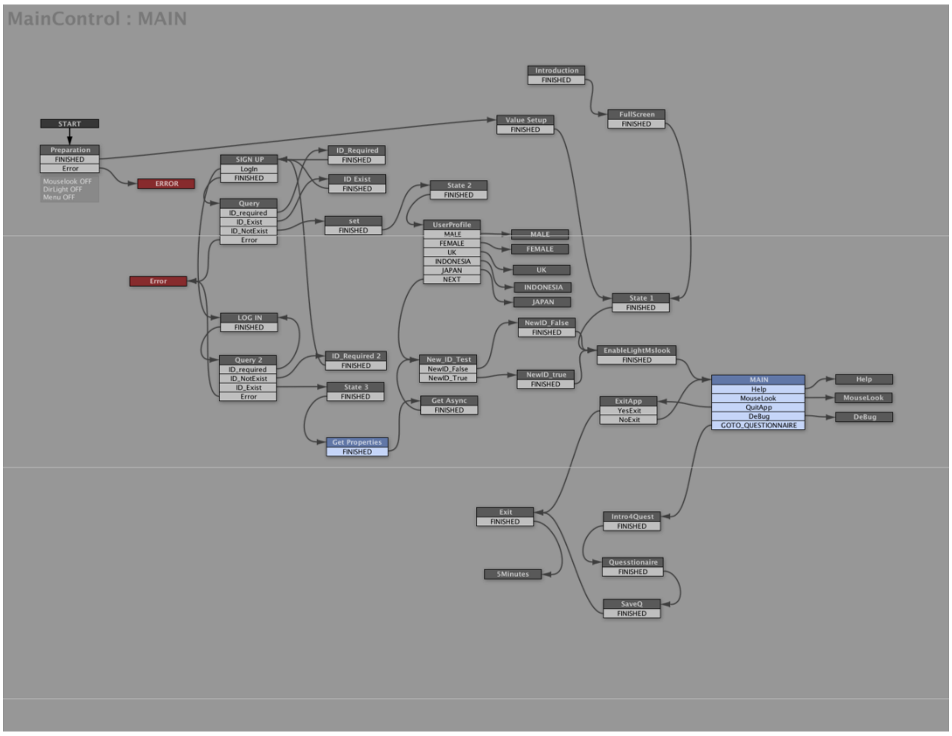
Designer D018

H.3. All Variables – Correlation Test (All Participants/ Designers1st/ Designers2nd)

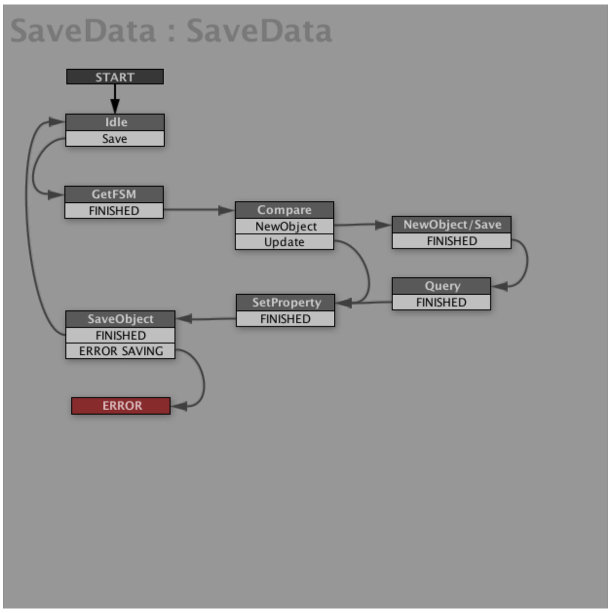
			All Participants	Des1st	Des2nd
Spearman's rho	All Participants	Correlation Coefficient	1.000	.561**	.573**
		Sig. (2-tailed)		0.000	0.000
		N	193	193	193
	Des1st	Correlation Coefficient	.561**	1.000	.647**
		Sig. (2-tailed)	0.000		0.000
		N	193	193	193
	Des2nd	Correlation Coefficient	.573**	.647**	1.000
		Sig. (2-tailed)	0.000	0.000	
		N	193	193	193
**. Correlation is significant at the 0.01 level (2-tailed).					

Appendix I. Examples of P-VE's Visual Scripting

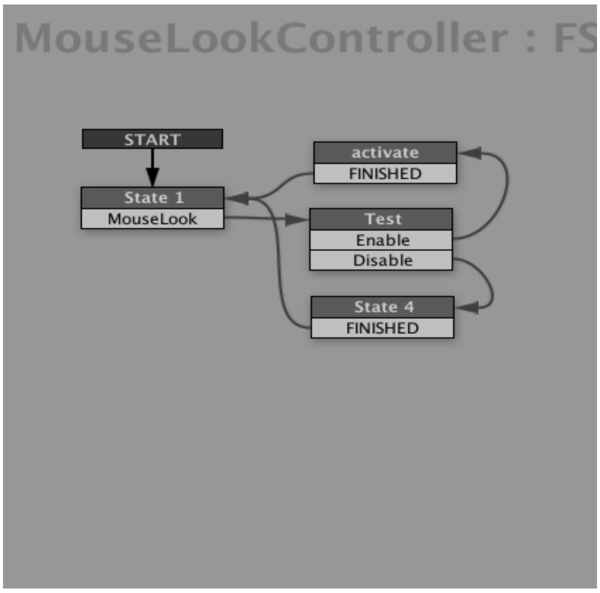
MainControl



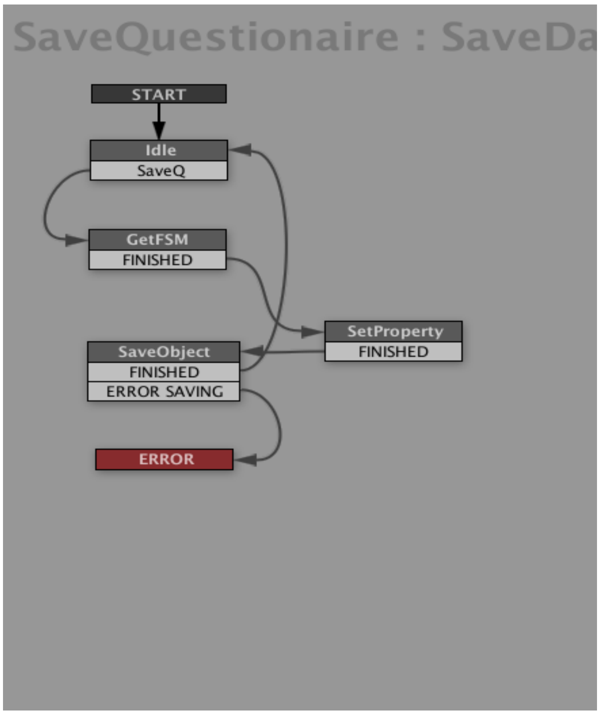
SaveData



Mouse Look Controller



Save Questionnaire



Appendix J. Ethic Approval

The University Of Sheffield.

Mr. Cahyono Priyanto
School of Architecture
University of Sheffield
The Arts Tower
Western Bank
Sheffield
S10 2TN

Tuesday, 25 September 2012

Stephen Walker

School of Architecture
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Western Bank
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S10 2TN

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Dear Cahyono

PROJECT TITLE: A STUDY OF USER VISUAL PREFERENCE OF LEARNING SPACE

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 25.06.12 the above-named project was **approved** on ethics grounds, on the basis that you will adhere to the following document that you submitted for ethics review:

- University research ethics application (submitted 10.08.2012)
- Participant Information Sheets and Consent Forms

If during the course of the project you need to deviate significantly from the above-approved document please inform me since written approval will be required. Please also inform me should you decide to terminate the project prematurely.

Yours sincerely

Stephen Walker
Ethics Administrator