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Investigating Student Satisfaction from Environmental and Architectural Design Elements of 3D Educational Facilities within 3D Virtual Worlds

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Abstract. Evolving online virtual worlds are intensely being utilised as 3D Virtual Learning Environments (3D VLEs) by hundreds of universities worldwide. However, there is inadequate academic research depicting satisfaction of users from the environmental design factors of 3D virtual buildings used within these virtual worlds. Specifically, there is no research evidence representing satisfaction of educational facilities' users, namely students and faculty, from the architectural design characteristics of their 3D virtual university campuses. This research focuses explicitly on capturing the contentment levels of students towards specified variations of certain architectural design elements of the 3D virtual learning spaces, where educational sessions are conducted in 3D VLEs. This hence provides preliminary guidelines on how to enhance the design of these spaces to augment e-learning experiences of students within 3D VLEs; achieved by analysing survey results representing students' opinions towards different architectural features of the learning spaces within different university 3D virtual campuses.

Keywords: virtual learning environments, architectural effects on e-learning, virtual architecture impact, 3D university design, building in Second Life.

1 Introduction

The innovation in e-learning techniques provided by 3D Virtual Learning Environments, such as Second Life, has encouraged many universities, such as Harvard, Princeton, Oxford, and over 400 more, to erect 3D virtual campuses for delivering e-learning to multiple diversities of students [1]. Such opportunities include experimentation, teleporting between sites [1], flying, game-based activities, role-play [2], modelling and co-creation, immersion, critical incident involvement, medical training [3] and many other practices.

Along with this trend emerged creative opportunities for constructing buildings that cross the boundaries of reality and delve into the realms of imagination of the designer. This is because of the essential disparity between the physical and the virtual world where there are (i) no constraints on budgets, (ii) no engineering natural forces and material strength limitations, (iii) no infrastructure requirements (e.g. sound, ventilation regulations or even gravity). For instance, gravity can be defied to have 3D virtual buildings floating in midair or immersed under the deepest ocean. Such novel construction techniques have also been used to erect virtual university campuses in 3D VLES to produce a wide variety of designs that range between realistic depictions or replicas of physically existing campuses, and completely imaginative embodiments [4].

However there is no academically conducted research that directly correlates between the new e-learning techniques explained above sprouting within 3D VLEs, and the design specifications of the 3D virtual spaces within which this e-learning is taking place. Therefore there is lack of supporting work on whether these design specifications have an impact on the effectiveness of e-learning on student users of 3D VLEs. One of the factors that have been proven to affect learning in the physical world, the degree of assimilation of knowledge, achievement and enjoyment of students from education, is the architectural design and physical building characteristics of the space in which students learn in. Such design features include colour, texture, dimensions of space, lighting, and ventilation amongst others [5]. On the other hand, sparse study explores the effect of 3D architecture in virtual worlds in general on any genre of users, not just students in 3D VLEs, and their satisfaction and contentment from it. For example a previous study examines systems for supplementing real-time 3D virtual environments to sustain the creation of their architectural designs [6]. Another study explores a collaborative learning approach to digital architectural design within a 3D real-time virtual environment [7]. Moreover, existing tutorials illustrating how to use building tools to construct within 3D VLEs only express how to create and edit these buildings [8], but do not offer any guidelines as to the specifications to take into consideration to make them functional, usable and acceptable by users. An individual market research, within Second Life, depicting users' reactions to preferences between realistic buildings and imaginative style buildings, only shows that users prefer realistic style buildings with a percentage of 60% more than their preference to using imaginative style 3D buildings [9].

As can be seen, there is no current research demonstrating the effect of 3D educational building architecture on student e-learning experiences, or their specific preferences and liking for the different design features of virtual buildings generally and virtual learning spaces specifically. Current research focuses on closing this gap by raising the query on and capturing the extent of students' satisfaction and contentment from specific internal architectural design elements of virtual educational buildings within 3DVLEs, hence giving the opportunity to issue recommendations for their future enhancement.

2 Method

To verify the above described uncertainty, it was imperative to investigate and analyse students' evaluative reactions towards the presence of certain variations of specific design elements within elected 3D virtual university campuses. This was accomplished by first selecting 16 virtual university campuses, within Second Life (as a representative of 3D VLEs), that embody 16 variations (described later) for 8 major internal architectural design elements used for building in the virtual world. The identified major architectural design elements were:

1. The architectural style of the 3D virtual building
2. The type of environmental surroundings seen through a 3D virtual space window
3. The internal wall design styles
4. The internal floor design styles
5. The learning space window design styles
6. The internal seating arrangements
7. The interior lighting level created by different percentages of open walls and roof
8. The interior space size and dimensions' ratio (width: length: height)

Despite the presence of other architectural design elements, only the above commonly used ones were selected since the purpose of the research was not to identify the effect of an exclusive list of elements on students, but rather to deduce whether internal architectural design elements in particular affect students' satisfaction from their 3D virtual learning space, hence indicating a possible effect on their learning experience during an e-learning session. A qualitative research approach was subsequently adopted, comprising of survey questionnaires containing closed and open ended questions [10], focus groups and interviews. However, the description and results of the students' survey closed-ended questions are the main interest and focus of this current paper (the other data being discussed by the authors in other submissions).The partaking sample of users consisted of 84 participants from the School of Engineering and Information Sciences in Middlesex University, UK. These were divided into the following categories which correspond to the different clusters of users utilising 3D virtual university campuses for e-learning sessions: 31 undergraduate students, 33 graduate students, and 20 members of faculty from different age groups (30 to 60 years old). The purpose of the study was explained to them, and only those volunteering to participate remained in the survey session, and were taken on a virtual tour inside Second Life, where they were shown each of the 16 nominated sites in sequence. After adequately interacting with each individual site and its spaces, participants answered a set of 9 Likert-scale questions that denote their opinion on how well they like each of the 8 previously mentioned design elements of that site, using a 7-level Likert-scale (strongly agree, agree, partially agree, neutral, partially disagree, disagree, strongly disagree) [11]. The questions were:

1. This learning space has an attractive building style (e.g. modern, classic, baroque)
2. This learning space has attractive surroundings (e.g. greenery, lighting, water)
3. This learning space provides a suitable seating arrangement (e.g. circular, rows)
4. This learning space provides a pleasant wall aesthetic/design (e.g. colours, texture)
5. This learning space offers a pleasant floor aesthetic/design (e.g. colours, materials)
6. This learning space provides pleasant window aesthetic/design (e.g. shapes, sizes)
7. This learning space provides sufficient lighting and open walls to the outdoors (percentage area of open to closed walls, windows and ceiling in the space)
8. This learning space offers comfortable dimensions and size for an educational environment (width to length to height area ratio)
9. This learning space offers a learning environment that you like to have classes in.

The last question was used as a benchmark to compare the average contentment derived from all other 8 elements against it.

3 Result

Since each 3D virtual site revealed to the student represented a variation for each architectural element (e.g. one building has wooden floors, whilst another uses marble), by finding the total number of student responses provided for each level of the Likert scale for each site (e.g. 7 strongly agree it's an attractive style whilst 2 partially disagree), it was possible to know the degree of satisfaction of the student body of participants from each variation of the tested architectural elements in this research. The resulting numbers were then multiplied by a factor (weight), as follows, and an average was found for each site to give an overall percentage of satisfaction for every 3D virtual architecture design feature represented by that site:

*((no. of strongly agree*100%) + (no. of agree* 66%) + (no. of partially agree*33%) + (no. of neutral * 0%) + (no. of partially disagree * -33%) + (no. of disagree * -66%) + (no. of strongly disagree * -100%)) / total number of participants * 100*

Positive factors indicate student satisfaction, whilst negative factors signify displeasure with the design element, where 100% denotes total satisfaction ("strongly agree"), 0% means indifference or "neutral" effect and -100% denotes total displeasure (strongly disagree). The 66%, 33%, -33% and -66% weights represent the even distribution of the other Likert scale values in between 100% and -100% based on importance. A similar data analysis method was adopted by Chan et al. [12].

Charts illustrating the different findings were then created to show the average percentage satisfaction scores for undergraduate students, post graduate students and their combined average, as demonstrated in the following sections.

3.1 Percentage Satisfaction of Students from the Architectural Style of 3D Virtual Buildings

As evident from the ensuing chart, the highest preference for 3D architectural styles was for the "modern" style and its similar relatives "Post Modern" "Richardsonian" (semi-classic) and "prairie" (organic) styles [13]. Conversely, least preferred styles include two categories: very futuristic and imaginative styles e.g. "high-tech", "Expressionist", "space" and "Deconstructivist" styles, and the other category is very ornate classical styles e.g. "Romanesque" and "baroque styles". This indicates that students prefer styles that are simple, not elaborate and similar to physical reality buildings where they take their real-life education. However there are apparent differences between undergraduates and post graduates in evaluating some of the more modernistic styles, where surprisingly under-graduates seem to dislike them a lot more than post- graduates, which might indicate a more open attitude to change by the latter, or maybe reveal a vulnerability, that under graduates are more distracted by sophisticated styles than post graduates during presence inside a 3D learning space.

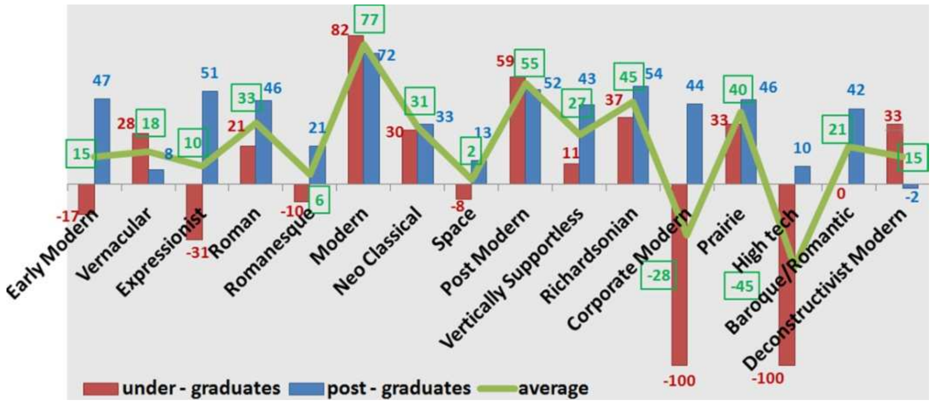

Fig. 1. Chart representing the percentage satisfaction of students from the different architectural styles of 3D virtual buildings in 3D VLEs

3.2 Percentage satisfaction of students from different Types of Environmental Surrounding

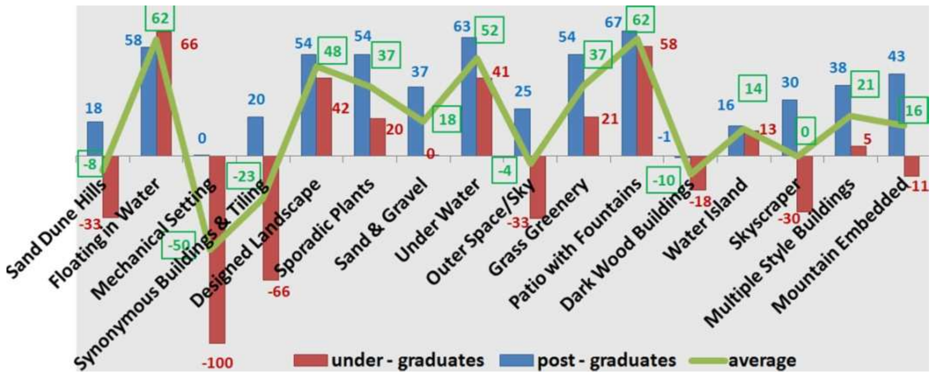

Fig. 2. Chart representing the percentage satisfaction of students from different types of environmental surroundings of 3D virtual buildings in 3D VLEs

The above chart shows that students in general feel most satisfaction within a 3D virtual learning space if they can see elements of water in the surroundings e.g. amidst “fountains” in outside patios, “under water” or “floating in water” (view of water in the horizon from the educational space windows). The least preferred environmental surroundings include rough strong features such as “dark wood” buildings, “mechanical settings”, replicas of imposing “high buildings” and empty desert “sand dunes” blocking the external view. Feasible fondness was also granted to organic and natural environmental features such as presence of “greenery”, “plants” and “designed landscapes”. Again this indicates similarity between student preferences in real life and virtual life where they prefer environments similar to their physical world to feel comfortable within their 3D virtual learning spaces.

3.3 Percentage satisfaction of students from Wall Design Styles

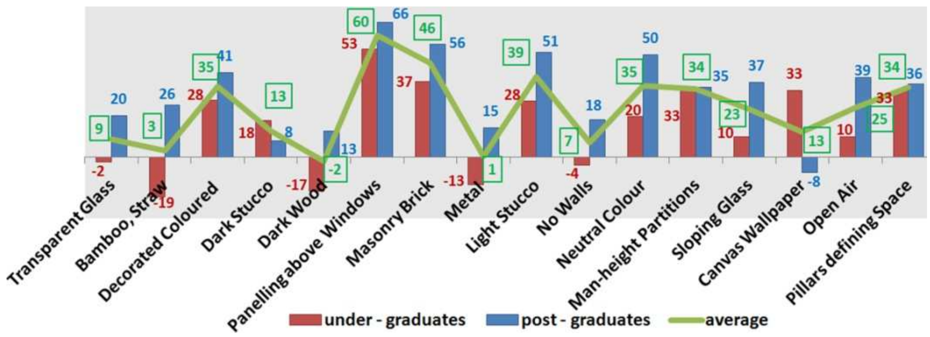

Fig. 3. Chart representing the percentage satisfaction of students from the different wall design styles of 3D virtual buildings in 3D VLEs

Preferences of students towards wall design are not confined to a particular style. Whilst usage of "panelling above windows" and "brickwork" appears to be popular, according to the results demonstrated in the above chart, there are other design styles that also appear to be quite favourable especially those involving decorated, coloured, light and neutral colours. Along the same vein as preferring half panelled-half window walls, presence of open space generally appears to be encouraged, for "open spaces defined by pillars" and "man height partitions" also scored considerably. Wall design styles that were completely disagreeable were those containing "dark colours" (wood or stucco), "metal", and less richer textures such as "straw, bamboo or canvas". Complete absence of walls with no definition for them was also unlikeable. This implies that students favour warm, bright and light colours in walls and prefer the boundaries of the learning space to be defined.

3.4 Percentage satisfaction of students from Floor Design Styles

Regarding floor designs, there does not appear to be a certain trend depicting satisfaction of students from a particular type of flooring material. For example it can be seen from the following chart results that "dark smooth carpeting" is highly favoured whilst "light rough carpeting" is not. However it is evident that, similar to wall design preferences, "dark wood", "rocks", "grass", "marble", and especially "concrete" are not preferred as flooring material, whilst lighter coloured materials such as vinyl, tiles and panels are more agreeable to be used in 3D virtual learning spaces. These results can imply that student satisfaction during e-learning sessions in 3D VLEs can be better achieved using light, bright or coloured floor finishing.

3.5 Percentage satisfaction of students from Window Design Styles

It is apparent from the consequent chart that large "bay" (multi – panelled) and "arched" style windows derive considerable satisfaction from students within 3D virtual educational spaces. Longitudinal "French" windows are also a very favourable style. On the contrary, having “skylights”, high “double-hung” style windows and unconventionally shaped windows e.g. “trapezoid” and “circular” is very undesirable. Presence of “closed walls” with no windows are obviously also disagreeable.

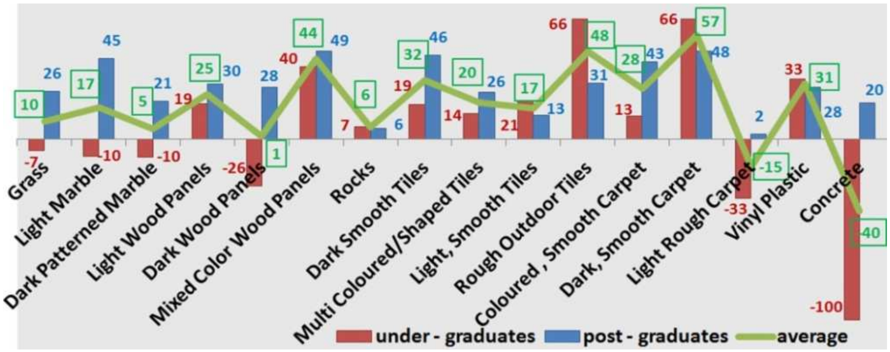

Fig. 4. Chart representing the percentage satisfaction of students from the different floor design styles of 3D virtual buildings in 3D VLEs

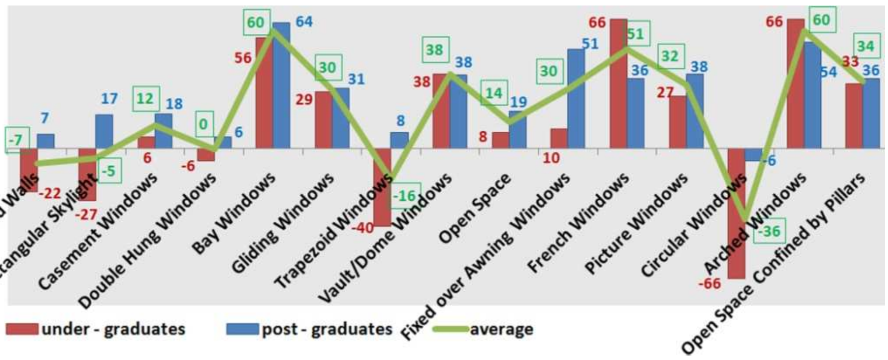

Fig. 5. Chart representing the percentage satisfaction of students from the different floor design styles of 3D virtual buildings in 3D VLEs

3.6 Percentage satisfaction of students from Different Seating Arrangements

Seating arrangements of students can be highly influential in the design of educational spaces, since the seating style can affect the shape of the whole building to suit the rows’ arrangement. According to the subsequent diagram, semi-circular and curved rows for seating are the most favourable and comfortable for students to use within 3D virtual educational buildings. Next come linear row arrangements in both closed theatres and open-air atriums. Despite their similarity with semi-circular arrangements, circular and oval arrangements of seats are surprisingly not preferable. Open spaces with no seats and floating seat arrangements are the least agreeable amongst students to be used in 3D VLE buildings. However, it can be seen that post-graduate students are more in favour of using floating seats than under-graduate students, complementing the previously recognized notion that post graduate students might be more open to innovative ideas, whilst under graduate students prefer non distracting stability and traditional seating arrangements.

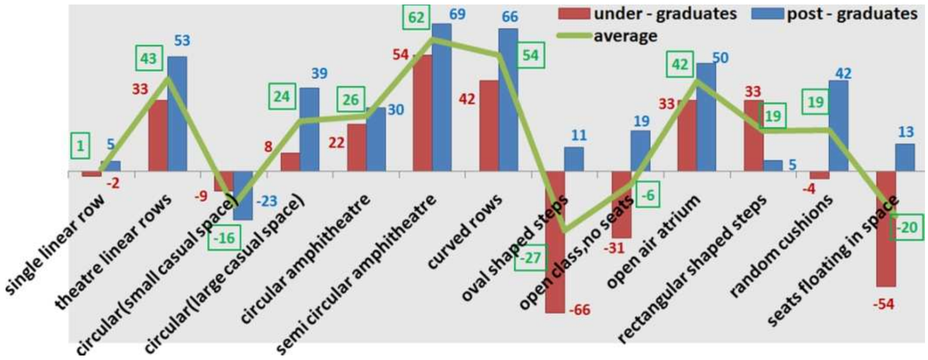

Fig. 6. Chart representing the percentage satisfaction of students from different seating arrangements in 3D VLEs

3.7 Percentage satisfaction of students from Interior Lighting Percentages

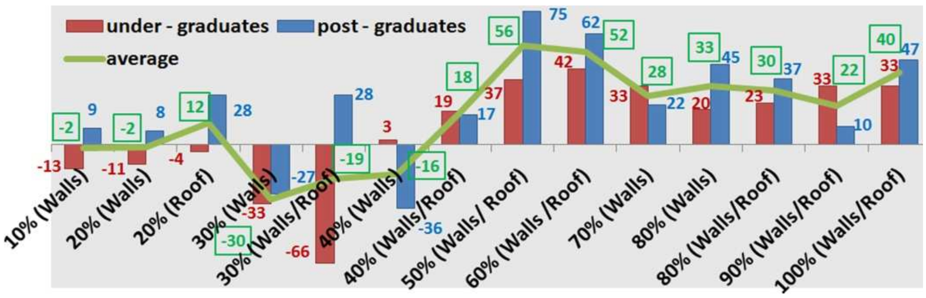

Fig. 7. Chart representing the percentage satisfaction of students from interior lighting resulting from different percentages of open walls & roof

For purpose of studying this design element, interior lighting intensity was considered proportional to the open surface area of the educational space in question. Hence the percentage of open to closed wall, ceiling and window area was calculated for each site, so that the higher the percentage, the more internal lighting is expected inside the space. The resulting chart shows that if percentage of open to closed wall and ceiling spaces is less than 40%, this is considered unfavourable providing uncomfortable internal lighting levels for students within the 3D virtual educational space. Highest satisfaction apparently accompanies a 50% - 60% open wall and ceiling area. An open area of 70% to 100% is also considered better than a 40% in providing satisfactory internal lighting as agreed upon by both under and post graduate students.

3.8 Percentage satisfaction of students from Interior Space Dimensions

The following chart clearly demonstrates that highest student satisfaction occurs on using circular and rectangular 3D virtual learning spaces with width: height ratio of

2:1. Also larger hall/amphitheatre dimensions are preferred to smaller classes to increase the perspective view of the student avatars within the virtual world. This coincides with findings from the previous section denoting preference of semi-circular seating arrangements most. Small class dimensions are shown to be the least favoured among students, regardless of the shape of the virtual space.

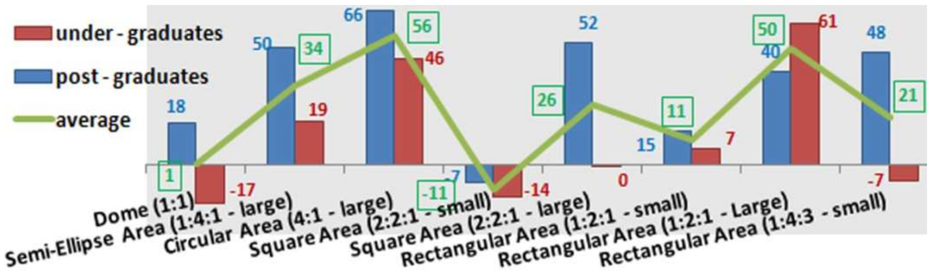

Fig. 8. Chart representing the percentage satisfaction of students from interior space size and dimensions (width: length: height)

3.9 Overall Percentage Satisfaction of Students from each Learning Space

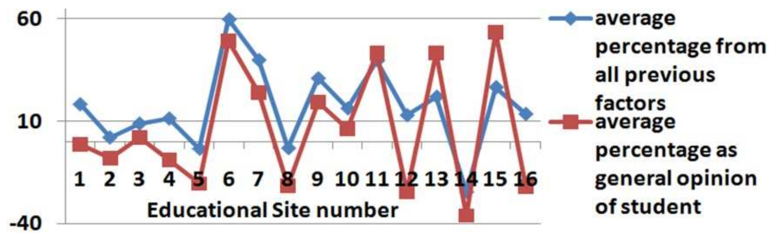

Fig. 9. Chart representing overall percentage of student satisfaction from each learning site

The overall percentage of student satisfaction from each of the 16 educational sites used in this research was calculated in two ways: 1) by calculating the average of the percentage satisfaction values of all the previous architectural design elements for each site used in this research. 2) by asking students directly to rank their satisfaction in general from each site using the same 7-level Likert-scale used within the survey questions. Plotting both results on chart reveals a high similarity between both values for most sites, the implications of which are explained henceforth.

4 Lessons learnt

It was interesting to observe the student behavioural patterns during the seminar sessions that took place during the pilot studies discussed in this paper. Throughout the learning experience of the students there were two key variables affecting their behaviour (i) the architectural changes and (ii) the learning activities. It was fascinating to investigate how the learning tasks were indirectly affected by the architectural elements.

Second Life avatars, despite being virtual representatives of student participants, demonstrated significantly varying behaviour during the session, primarily by exploring the environment while participating in learning activities. It could be argued that an environment that could be less than a unique experience to them might be less destructive. Alas, participants of follow up sessions still proceeded with an investigation of the surroundings while answering questions, interacting with the speaker and their team members.

The inhibiting factors affecting human behaviour in traditional classrooms were partly removed by the lack of face to face contact as indicated by the way avatars were presented and even interacted with instructors. However, it is interesting to see how conventional classroom artifacts were completely ignored by the students (e.g. positioning of podium, chairs, tables, white boards).

Another lesson related to the architectural changes affecting the learning experience of those involved: it was evident that the volatile environment offered by virtual world technology should maintain the characteristic of an ever changing learning space rather than simulating the rigid settings we experience in real world scenarios. The fact that room shapes, colours, window sizes and space were changed to accommodate different aspects of the learning activity allowed participants to engage without major environmental obstructions. It seems that endless opportunities open up in the field of designing learning spaces and preparing learning activities.

5 Conclusion and Implications

The contributions presented by this research paper lie at the intersection of e-learning, architecture and 3D virtual product design as elaborated hereafter.

The resemblance between the two values obtained in the previous section, depicting overall student satisfaction from each 3D virtual educational site, indicates that this satisfaction in general is heavily dependent on the 8 major architectural design elements discussed within this research, thus enforcing the importance of architectural design features of a 3D virtual educational space on the contentment of students. Moreover, since enjoyment is proven to affect levels of understanding [11], this signifies that design elements can affect quality of e-learning experiences within 3D educational spaces, which is the subsequent extension to this research to examine.

Furthermore, the previously identified student preferences, for example use of modern design style, landscaping using water elements, using light bright colours for wall and floor designs, bay, French or arched windows to cover 50% of the surface area of circular or rectangular spaces, can provide opportunities to issue recommendations for future enhancement of 3D educational spaces within 3D VLEs.

Consequently, by investigating the satisfaction of students from specific design elements of an educational building, this research can also enforce the initialization of a framework of building codes, for constructing educational facilities within 3D Virtual Environments, to complement existing codes for erecting such facilities in the physical real-life world. This is vital to boost the e-learning experience of students within their 3D virtual learning spaces.

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