

Effects of Virtual World Environments in Student Satisfaction: An Examination of the Role of Architecture in 3D Education

Noha Saleeb, Middlesex University, UK

Georgios Dafoulas, Middlesex University, UK

ABSTRACT

Universities and educational institutions worldwide are currently becoming more dependent on delivering assorted courses within online virtual worlds as 3D Virtual Learning Environments (3D VLES). Nonetheless there is insufficient study of how environmental and architectural design elements of 3D virtual educational spaces and buildings inside these virtual worlds can affect the e-learning process of the students and their satisfaction and contentment within them. Thus this study investigates students' satisfaction from different architectural features used in 3D educational facilities by recording, from surveys, students' degree of agreeability towards varied design characteristics in different learning spaces within 3D VLEs. Defining best perceived design traits can allow for improvement of 3D educational space design to augment a student's overall e-learning experience, and allow for issuance of general design guidelines for future creation of 3D virtual educational facilities.

Keywords: virtual learning environments, 3D virtual world, Second Life, virtual learning space, 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 (Joseph, 2007). Such opportunities include experimentation, teleporting between sites (Joseph, 2007), flying, game-based activities, role-play (Calongne, 2008), modeling and co-creation, immersion, critical incident involvement, medical training (Scopes & Lesley, 2009) 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 (Alarifi, 2008).

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.

2. BACKGROUND

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 color, texture, dimensions of space, lighting, and ventilation amongst others (Fink, 2002). 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 (Reffat et al. 2008). Another study explores a collaborative learning approach to digital architectural design within a 3D real-time virtual environment (Reffat, 2005). Moreover, existing tutorials illustrating how to use building tools to construct within 3D VLEs only express how to create and edit these buildings (Nesson, 2007), 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 (Market truths Limited, 2009). Further evidence by Pursel (2010) indicates that virtual usability criteria of 3D buildings in general can differ to usability criteria required in the physical world. He includes an example of the virtual Ohio University campus, that while being an exact replica of reality, the presence of so many storeys and internal corridors is extremely inconvenient to travel through in virtual worlds (too narrow, difficult to navigate, falling off stairs, difficult exits). He also recommends that museum exhibits be placed on outer glass windows of a building, instead of on internal walls, and avatars can fly up and admire them from the outside of the building. He also comments that lecture halls in virtual worlds that are created with the same dimensions and chairs as in the physical world are very crowded and provide bad circulation. Hence it can be seen that students' contentment and satisfaction from design elements of learning spaces in 3D virtual worlds can be different from those in the physical world.

A unique project dedicated to creating a generative architectural virtual campus of a Real Life University in Second Life, was designed around a core spiral structure so that the virtual building re-configures itself based upon user demand, adding exhibition and meeting areas as well as conference halls and auditoriums, as and when required (Ayiter et al., 2009). This project seemingly revolves around users or learners' requirements for a suitable learning environment, which is a required initiative. It was therefore imperative for the researchers within the current study to investigate whether any general design codes, architectural specifications or guidelines were followed to realize this construction, or whether the design concept was based on or reflects in any way

student satisfaction and contentment. However the following was revealed:

- The choice of the spiral shape was not based on any study depicting learners' preferences or satisfaction from this shape. It was rather chosen for its ease of manipulation as a shape that can be extended architecturally, and also for its resemblance to famous architectural buildings - the Spiral Minaret of the Great Mosque at Samarra, built in 847, AD, and one imaginary - the Tower of Babel as envisioned by Brueghel the Elder. Neither of the two buildings was an educational facility.
- The dimensions chosen to create new classes, halls etc. were not based on any research defining appropriate area requirements for virtual learners' usage. Even then, only the width and length (x and y axis) of the space were increased with any addition in the number of users, while the height (y-axis) was completely disregarded for ease of design, even though it is expected that with an increase in the number of learners, the height should also be increased to maintain aspect ratio of the space dimensions and to allow proper visibility with distance, and tolerate flying action of avatars.
- There is no emphasis on internal design features e.g. finishing, color, open wall areas etc.

While the innovation provided by the above examined project gives way for interactive educational facilities' design, it emphasizes the need for presence of 3D virtual architectural specifications to govern design of the learning spaces to provide optimum e-learning conditions for students.

There are also only some general recommendations or guidelines offered by previous researchers interested in design of virtual environments, based on observation and interviews with 3D VLE general users (not on interaction of the learners with the environment during the e-learning process), to aid design 3D virtual educational spaces. For example Dickey (2004) suggests using architectural and environmental elements such as landmarks, signs, paths (easily identifiable starting point, course, intersections and destination), thresholds (e.g. doorways expressing relationship of the space with the surroundings) and boundaries (fences, walls etc.) to aid students' way finding, or using large scale spaces (but with no detailed specifications provided) (Charitos, 1998), or Feng-Shui flow of navigation style of design (Heim, 2001). Bridges & Charitos note that real world elements, e.g. doors, roofs, columns, structural or ornamental details, should only be used if there is a functional use for them (e.g. no door if the walls are penetratable) (Bridges & Charitos, 1997). Minocha & Reeves (2009) further propose using "open spaces as much as possible" to accommodate flying, wide corridors, realism in design, and arrangement of spaces to follow activities performed in them. As for the factors

affecting the level of engagement experienced by the learners, only pedagogical factors were identified not architectural factors (Minocha & Mount, 2009). A research on user orientation within 3D VLEs was conducted by Charitos (1999) showing that the application of any rotation on the 3D build in relation to the path clearly decreases the easiness with which a person orientates in this place, although this is unlikely to occur during an e-learning session. Furthermore, based on other conducted experiments, Bridges & Charitos (2001) affirmed that in general design of virtual environments, avatar movement in a virtual environment is significantly enhanced by the use of “dynamic textures and rhythmically repeated elements in paths”. Charitos also confirmed that ratio of dimensions of a space can induce avatar movement towards the centre or the boundary of that place (if square) or along its main axis (if horizontal or vertical) - hence a virtual space which has the volumetric proportions of a ‘run’ (i.e. one dimension is more than 2 or 3 times the other dimensions) induces movement towards the direction it implies (Charitos, 2005). However:

- There is no indication how this feature (or any of the above attributes mentioned in general) affects the e-learning experience in 3D VLEs or 3D educational facilities.
- Even more, while Norberg-Schulz (1996) describes a place as “a totality made up of concrete things having material substance, shape, texture and color”, and Bridges & Charitos (1997) state that the overall impact of an object in a virtual world is determined by its geometry, color, texture etc., there is no recorded research of impact of specific architectural elements e.g. color, texture, shape, dimensions, seating arrangements, lighting etc. on students or users in general;
- Nor students’ specific preferences and proposals for these different architectural design features of virtual learning spaces, especially towards the newly emergent types of architecture in virtual worlds that are not available in the physical world.
- In addition, while Bridges & Charitos (1997) also state that virtual building design should not imitate physical building design to detail, no comparisons are available showing the difference between presence of a certain architectural characteristic or dimension etc. in the physical world and its counterpart in the virtual world.

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. 3D virtual educational facilities are currently being created mainly in ad hoc fashion, according to each designer’s perceptions or

taste, with no specific design guidelines (Bridges & Charitos, 2001). The 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.

3. RESEARCH RATIONALE

To verify the above described uncertainty, it was imperative to investigate and analyze 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 sites included within this study comprise of: Purdue University, Harvard University (Austin Hall, Berkman Island), Incubator Island, University of South Mississippi, Louisiana University (Monroe Island), Insight Virtual College, Princeton University, and the Open University. The identified major architectural design elements to be tested 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 mixed quantitative / qualitative research approach was subsequently adopted, comprising of survey questionnaires containing closed and open ended questions (Johnson & Christensen, 2004), 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) representing adult learners. 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. They were also asked to sign, with their real name and avatar name, a consent document to participate inside Second Life, in the form of a notecard to be handed to the researchers' "in-world" inventory of items. 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 liked 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) (Mitchell et al., 2005). The questions used within this study 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 features)
3. This learning space provides a suitable seating arrangement (e.g. circular, rows, random, suspended in space)
4. This learning space provides a pleasant wall aesthetic/design (e.g. colors, texture)
5. This learning space offers a pleasant floor aesthetic/design (e.g. colors, 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, shape and size for an educational environment (width to length to height area ratio)
9. This learning space offers a learning environment that you would 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.

4. DISCUSSION OF RESULTS

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 students 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 for each question were then multiplied by a factor (weight), described henceforth, 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.

For each site in every question, the percentage overall satisfaction from each design element in that site was calculated as follows:

$$\left((no. \text{ of strongly agree votes} * 100\%) + (no. \text{ of agree votes} * 66\%) + (no. \text{ of partially agree votes} * 33\%) + (no. \text{ of neutral votes} * 0\%) + (no. \text{ of partially disagree votes} * -33\%) + (no. \text{ of disagree votes} * -66\%) + (no. \text{ of strongly disagree} * -100\%) \right) / \text{Total number of participants} * 100$$

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. (2004).

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. Results for adult learners comprising of members of staff were omitted within this paper to be included in another publication with their conducted interviews.

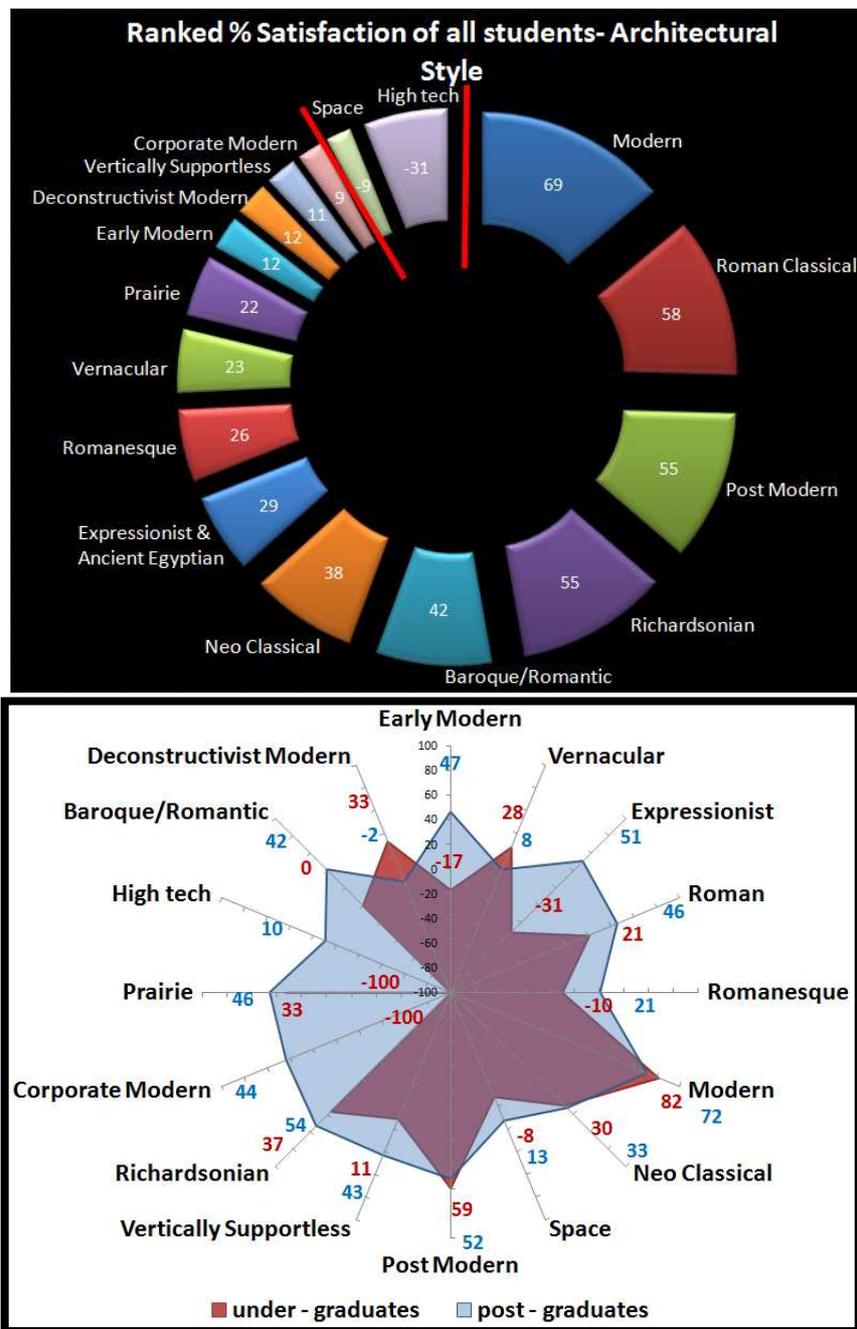
Percentage Satisfaction of Students from the Architectural Style of 3D Virtual Buildings

As evident from the ensuing Figure 1, the highest preference for 3D architectural styles was for the "modern" style and its similar relatives "Post Modern" and "Richardsonian" (semi-classic). "Roman

Classical” was also a favored style which may be due to its plain non-ornate characteristics unlike other classical architectural styles. As evidence of this suggestion, it can be seen that very ornate classical styles e.g. “Romanesque” and “baroque styles” were

not very much in preference. Conversely also, the least preferred styles include two categories: very futuristic and imaginative styles e.g. “high-tech”, “Corporate Modern”, “space” and “Deconstructivist”.

Figure 1. The percentage satisfaction of students from the different architectural styles of 3D virtual buildings in 3D VLEs: a) for all students b) by category of students



This indicates that students prefer styles that are simple, not elaborate and similar to physical reality buildings where they take their real-life education.

When they were asked for reasons behind this preference, students indicated that it provided less cluttering and distraction towards the surroundings.

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 intimidated or distracted by sophisticated styles than post graduates during presence inside a 3D learning

space. Post-graduates also seem generally open to favoring different architectural styles more than under-graduates who appear to have definite strong inclinations towards or away from certain styles.

Percentage satisfaction of students from different Types of Environmental Surrounding

Figure 2. The percentage satisfaction of students from different types of environmental surroundings of 3D virtual buildings in 3D VLEs: a) for all students b) by category of students

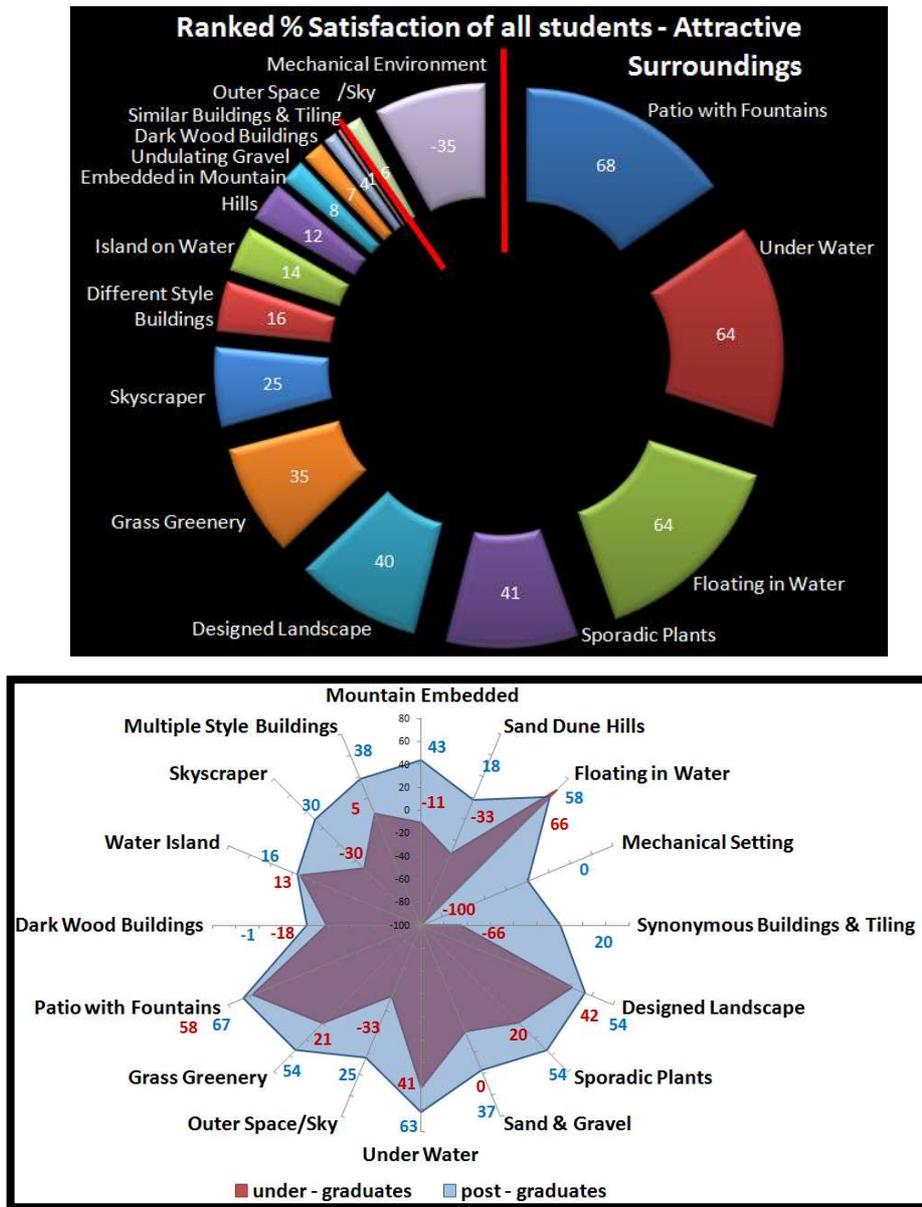


Figure 2 shows that students in general feel most satisfaction within a 3D virtual learning space if they

can see elements of water in the surroundings e.g. amidst “fountains” in outside patios, “under water” or

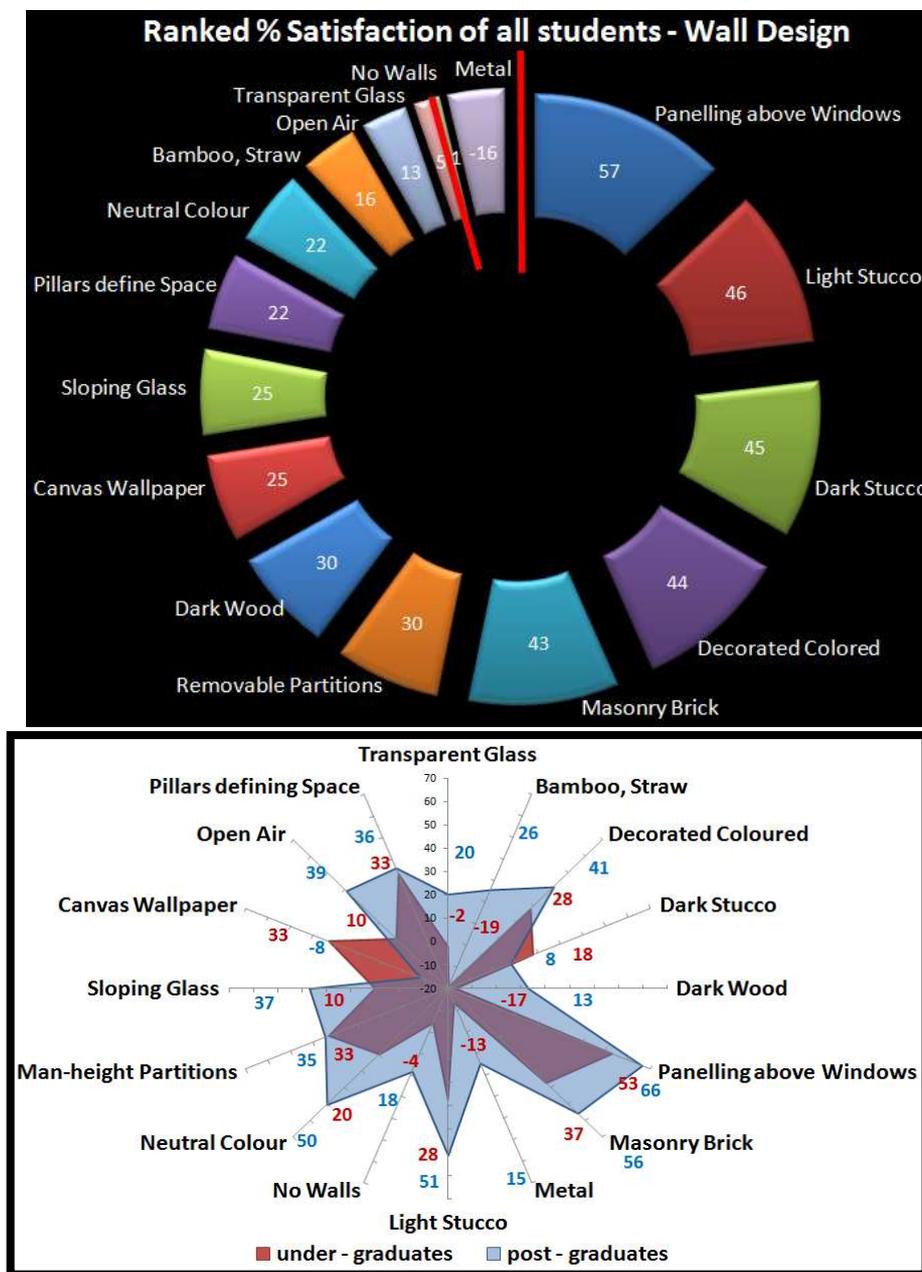
“floating in water” (view of water in the horizon from the educational space windows). The least preferred environmental surroundings include rough strong features such as “dark wood” buildings, “mechanical settings”, replicas of imposing “high buildings” and empty desert “sand dunes” blocking the external view. Being in “outer space” and unfamiliar “mechanical” or technical environment also seemed a deterrent. On the other hand, feasible fondness was granted to organic and natural environmental features such as presence of “greenery”, “plants” and “designed landscapes”. It can be repeatedly seen here, similar to

the previous section, that post-graduates show more flexibility towards different environmental features than under-graduate students.

Again the above mentioned points indicate 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.

Percentage satisfaction of students from Wall Design Styles

Figure 3. Percentage satisfaction of students from different wall design styles of 3D virtual buildings in 3D VLEs: a) for all students b) by category of students

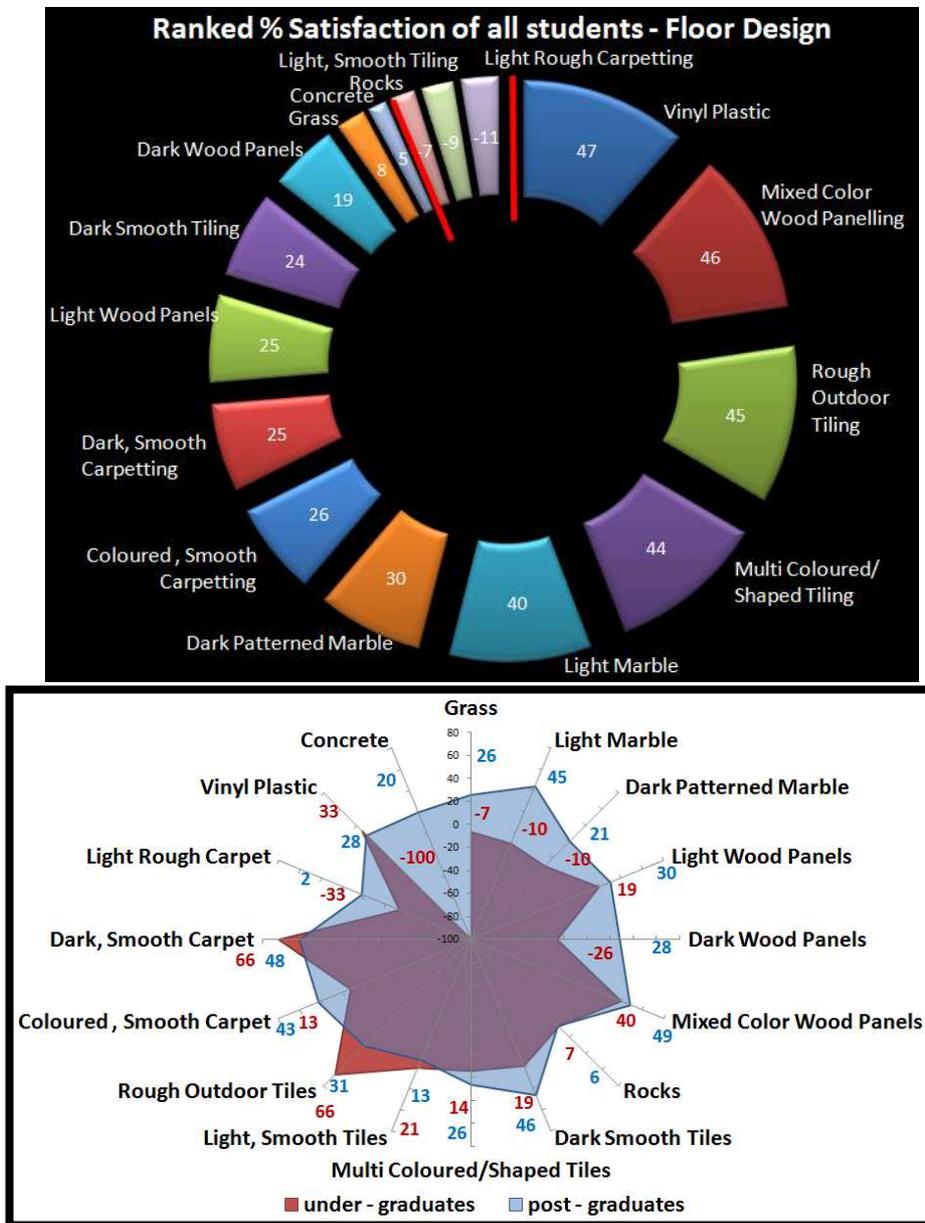


Preferences of students towards wall design are not confined to a particular style. Whilst usage of “paneling above windows” and “brickwork” appears to be popular, according to the results demonstrated in Figure 3 above, there are other design styles that also appear to be quite favorable especially those involving decorated, colored, light and neutral colors. Along the same vein as preferring half paneled-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 colors” (wood or stucco), “metal”, and less richer textures such as “straw, bamboo or canvas”. There is a conflict in opinion between under-graduates and post-graduates regarding preference towards wallpaper. Complete absence of walls with no definition for space was also unlikeable. This implies that students favor warm, bright and light colors in walls and prefer the boundaries of the learning space to be defined.

Percentage satisfaction of students from Floor Design Styles

Figure 4. Percentage satisfaction of students from the different floor design styles of 3D virtual buildings in 3D VLEs: a) for all students b) by category of students

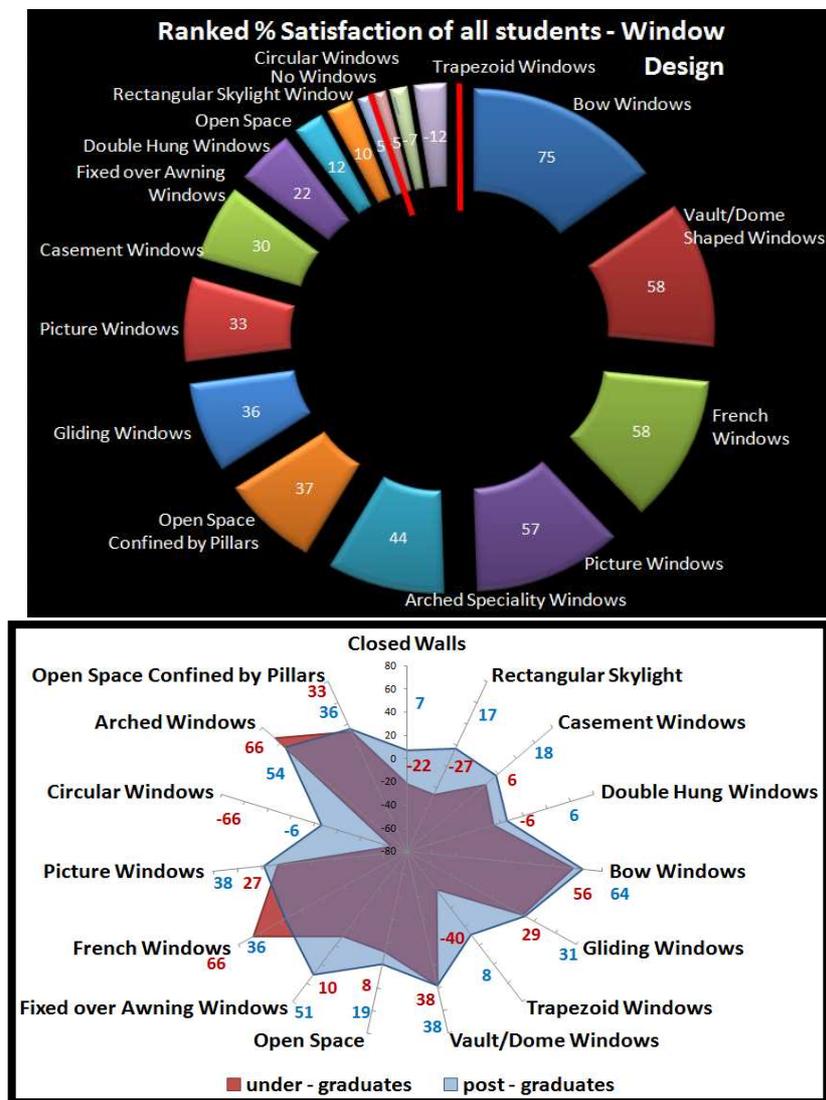


Regarding floor designs, there does not appear to be a certain trend depicting satisfaction of students from a particular type of flooring material. For example it can be seen from the following Figure 4 results that multi-colored flooring is highly favored. However it is evident that, similar to wall design preferences, “dark wood”, “rocks”, “grass”, “marble”, and especially “concrete” are not preferred as flooring material, whilst lighter colored 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 colored floor finishing.

Percentage satisfaction of students from Window Design Styles

Figure 5. The percentage satisfaction of students from the different window design styles of 3D virtual buildings in 3D VLEs: a) for all students b) by category of students



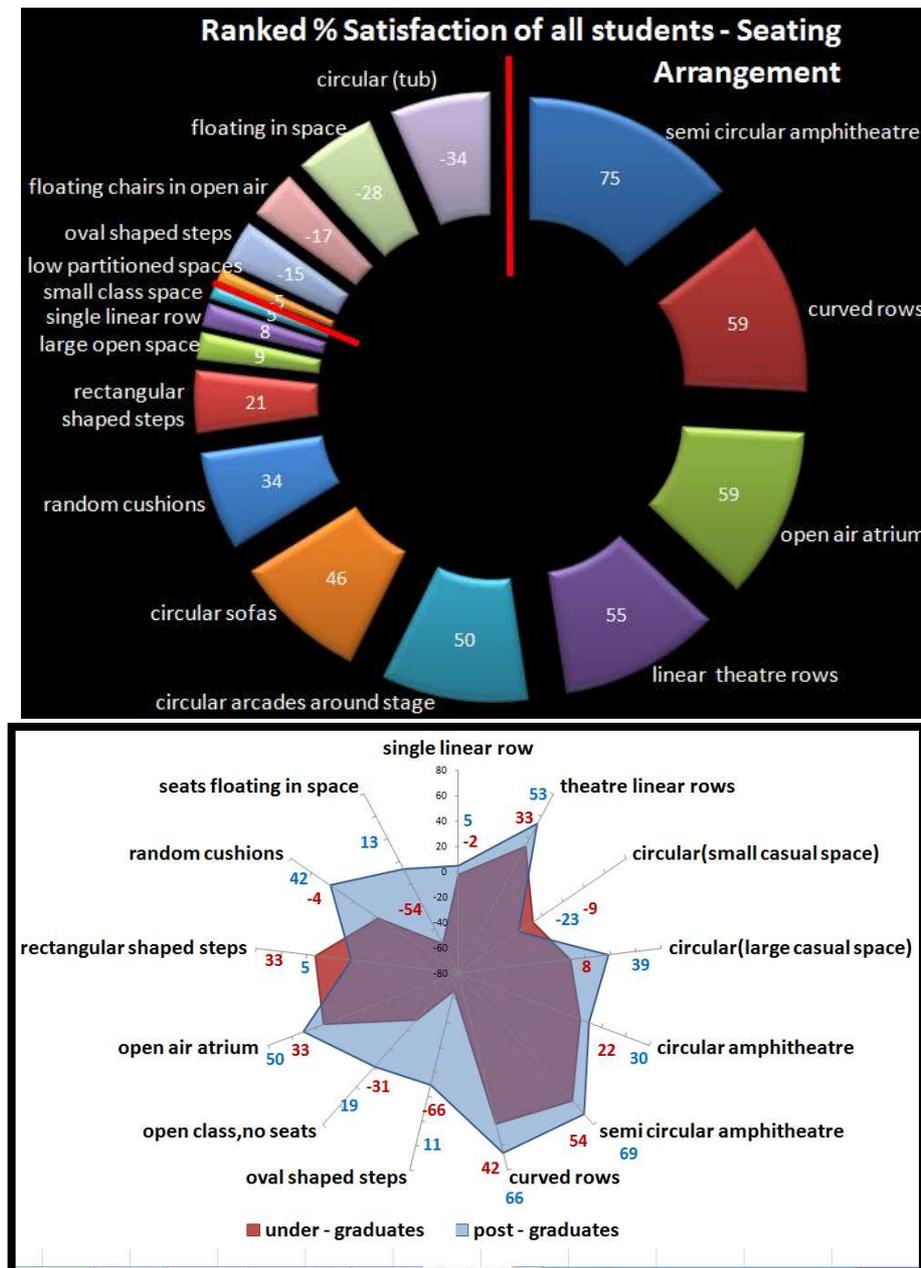
It is apparent from the consequent Figure 5 that large “bow” (multi – paneled) and curved style windows (“arched”, “dome”, “vault”) derive considerable satisfaction from students within 3D

virtual educational spaces. Longitudinal classical “French” windows are also a very favorable 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. Again here, like demonstrated before, there is a confirmation that open space defined by pillars is agreeable among students.

Percentage satisfaction of students from Different Seating Arrangements

Figure 6. The percentage satisfaction of students from different seating arrangements in 3D VLEs: a) for all students b) by category of students



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 Figure 6, semi-circular and curved rows for seating are the most favorable and

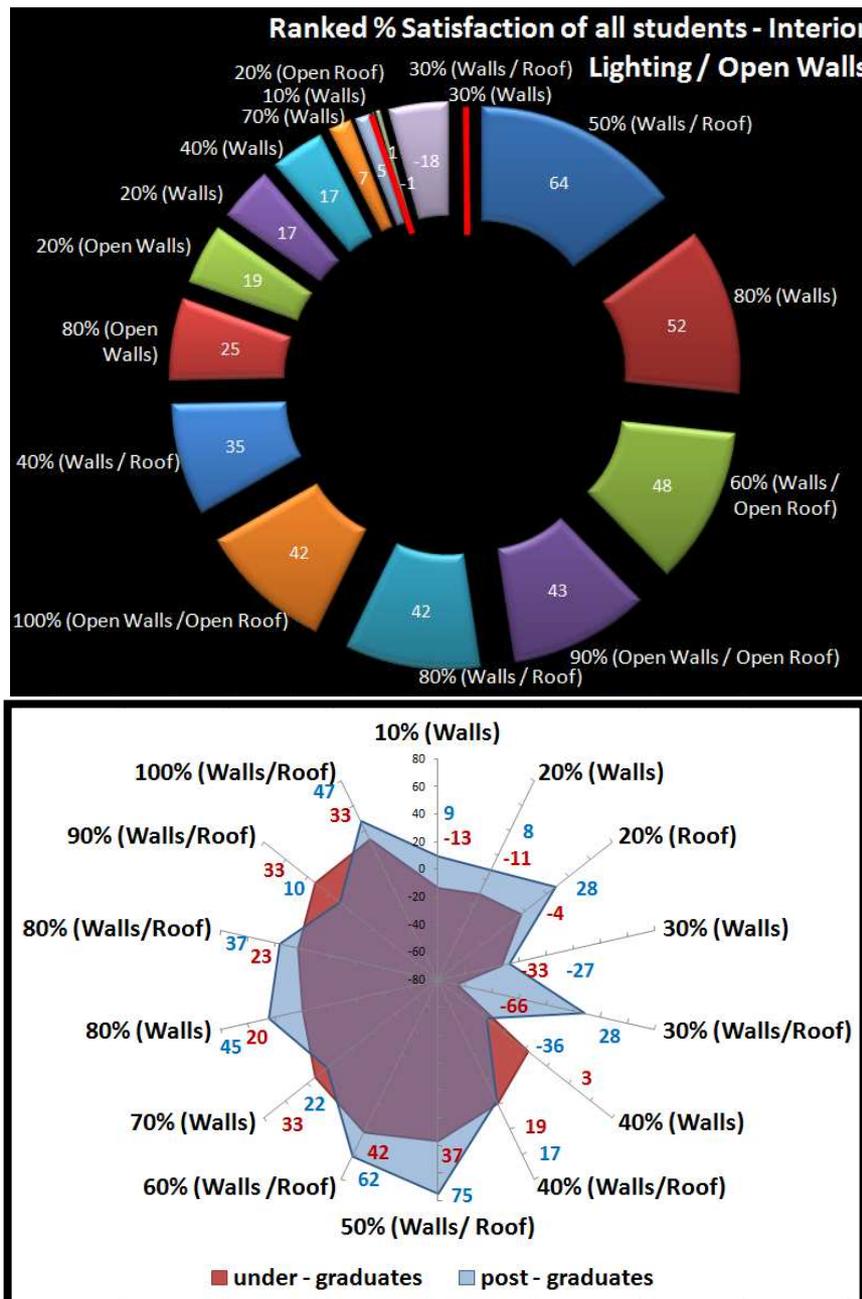
comfortable for students to use within 3D virtual educational buildings. Next come linear row arrangements in both closed theatres and open-air atriums. Despite their similarity with semi-circular arrangements, complete circular and oval arrangements of seats are surprisingly not preferable.

Open spaces with no seats and floating seat arrangements are the least agreeable amongst students to be used in 3D VLE buildings. This result coincides with previous findings denoting disagreeability of architectural styles that use a space or floating theme, no vertical supports etc. However, it can be seen that post-graduate students are more in favor of using floating seats and random seating than under-graduate

students, complementing another 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 depicting reality.

Percentage satisfaction of students from Interior Lighting Percentages

Figure 7. The percentage satisfaction of students from interior lighting resulting from different percentages of open walls & roof in 3D VLE spaces: a) for all students b) by category of students



Saleeb, N. & Dafoulas, G. (2011), 'Effects of Virtual World Environments in Student Satisfaction: An Examination of the Role of Architecture in 3D Education', *International Journal of Knowledge Society Research (IJKSR)*, vol. 2, no.1, pp.28-48

Interior lighting is denoted by Fielding (2006) as one of the essential elements for defining educational facility design with minimum recommendations for 50 feet vistas in learning spaces, For purpose of studying this design element for 3D virtual learning spaces, interior lighting intensity was considered proportional to the open surface area of the walls and ceiling 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 Figure 7 below shows that if percentage of open to closed wall and ceiling spaces is less than 40%, this is considered unfavorable 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, but still is not as preferred as the sense of comfort provided by 50-60% open wall and ceiling area. Post-graduate students also seem to show more tolerance towards

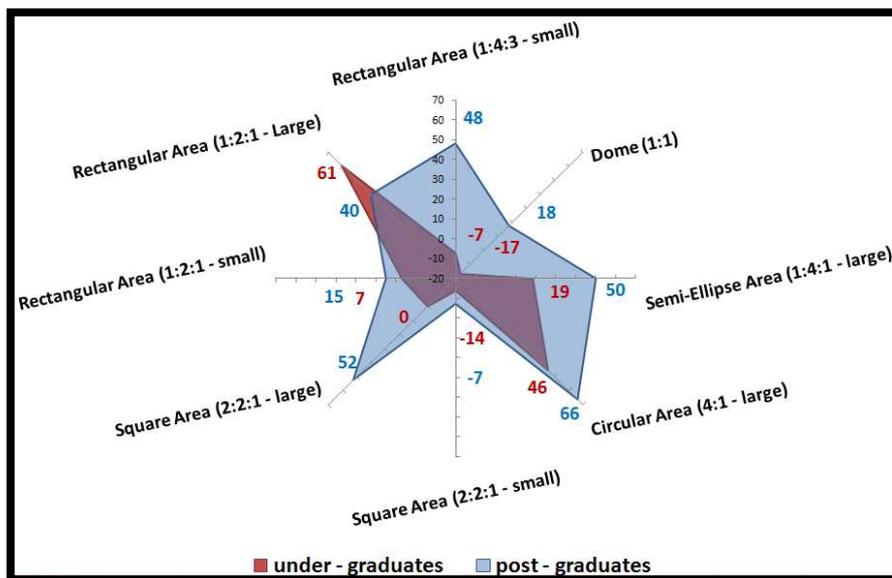
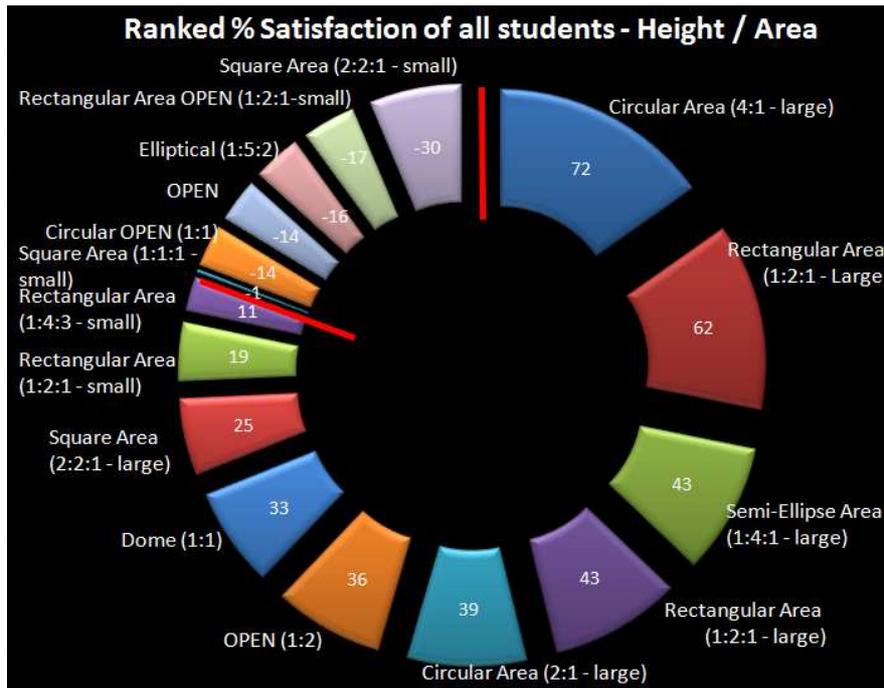
low interior lighting percentages than under-graduate students.

Percentage satisfaction of students from Interior Space Dimensions

Figure 8 above clearly demonstrates that highest student satisfaction occurs on using circular and rectangular 3D virtual learning spaces with width: height ratio of 2:1. This coincides with findings from the previous section denoting preference of semi-circular seating arrangements most. Also larger hall/amphitheatre dimensions are preferred to smaller classes to increase the perspective view of the student avatars within the virtual world. Small class dimensions are shown to be the least favored among students, regardless of the shape of the virtual space; Also the larger the height of the space, the better to accommodate avatar flying motion.

Again here, similar to previous sections, post-graduates demonstrate more lenience towards being in educational spaces of different shapes and dimensions than under-graduates who are very biased towards large circular and rectangular shapes.

Figure 8. The percentage satisfaction of students from interior space size and dimensions (width: length: height) of 3D VLEs: a) for all students b) by category of students



Overall Percentage Satisfaction of Students from each Learning Space

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 as shown in Figure 9 reveals a high similarity between both values for most sites, the implications of which are explained henceforth.

On further examination of the previously mentioned result using the following detailed Figure 10 which depicts the major architectural properties of each site, it can be seen that:

- General satisfaction of students from the educational sites, calculated using both methods mentioned above, is almost identical for nearly half the sites

- These sites are the ones containing either a combination of the best preferred architectural elements (e.g. 50% opened wall/roof areas, light or mixed colors, arched or bowed windows etc.) or a combination of the least preferred architectural elements (less than 50% opened wall/roof areas, dark colors, non-curved windows etc.)
- Even the sites which did not give identical results for the 2 percentage satisfactions for each site, calculated using both methods stated above, showed very similar results.

Whether there is similarity or identity, both designate that overall satisfaction of a student from an educational space is highly dependent on its 8 architectural elements tested for previously, evidenced by the fact that taking a mean value for the 8 elements of a site is very similar to the general satisfaction of the student from that same site. This confirms the hypothesis that architectural design elements of 3D virtual educational facilities have an impact on students.

Figure 9. Overall percentage of student satisfaction from each learning site

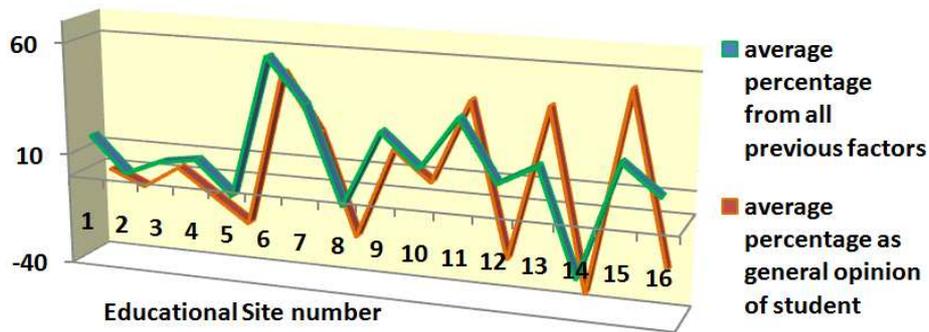


Figure 10. Overall percentage of student satisfaction from each learning site

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.

6. CONCLUSION AND IMPLICATIONS

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

One of the most significant findings within this study is the resemblance between the two values obtained in the previous results, depicting overall student satisfaction from each 3D virtual educational site (calculated from i) the average of all 8 characteristics of a site, and ii) in general). This indicates that satisfaction of users in general from a learning space 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 (Charitos, 1998), 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 colors 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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