ISSN (Online): 1694-0784
ISSN (Print): 1694-0814

Relationship between Students' Overall Satisfaction from 3D Virtual Learning Spaces and their Individual Design Components

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Abstract

3D virtual worlds, such as Second Life, are increasingly being used for delivering e-learning for different genres of students. As part of an ongoing research to evaluate different digital design aspects of using these emergent virtual learning environments, the aim of this paper is to investigate whether the overall satisfaction of students from their 3D learning spaces is dependent on their satisfaction and contentment from specific individual architectural elements used to design these educational spaces and buildings. This is depicted through investigating the correlation between students' satisfaction from individual space design elements and overall satisfaction from diverse e-learning venues within Second Life. Furthermore this study contrasts the difference in response rates between different student categories to the perception of suitability of educational space design for conducting e-learning sessions.

Keywords: *3D virtual worlds, virtual learning environments, e-learning spaces in Second Life, 3D architectural design for educational facilities.*

1. Introduction

3D online virtual worlds have been progressively utilized over the past decade as 3D virtual learning environments (3D VLEs) by hundreds of universities and educational facilities for a variety of e-learning purposes within many fields including computer science, medicine, law, engineering, architecture, business, art, humanities and many more [1]. This existence has necessitated the erection of virtual campuses for universities and educational institutions inside these environments such as Active Worlds, Blue Mars, OS Grid, and the more prominently used Second Life [2]. While designers and builders have strived to erect assorted styles of buildings inside 3D VLEs to accommodate students in realistic, creative and imaginative constructions, there is no evidence in prior research that pinpoints presence of any architectural codes or specifications for designing 3D virtual educational spaces [3]. These are design codes and guidelines that should be incorporated in current virtual creations to provide the optimum environment for enhancing a student's e-learning experience through increased satisfaction, participation, retention, enjoyment etc. [4]. On the contrary, 3D educational facilities are currently being created on an extemporized basis according to individual perception and experience of each individual virtual world designer from designing in the "real-life" physical world [5]. This contradicts views by Bridges & Charitos [5] which state that virtual building design should not imitate physical building design to detail since virtual usability criteria of 3D buildings in general can differ to usability criteria required in the physical world [6].

It hence becomes imperative to investigate the effect of the architectural design elements of existing 3D virtual educational facilities on the students using them and their e-learning experiences in an attempt to find the most suitable design criteria for future usage. This would entail, as part of the process, examining the satisfaction percentage levels of students from a range of 3D learning spaces that contain different variations of architectural components or features.

2. Research Rationale and Methods

As part of an ongoing research to uncover the effect of different architectural design elements of 3D virtual learning spaces on a student's e-learning experience, a study was conducted to record the satisfaction level of students from different variations of specific architectural features in selected learning spaces.

Eleven university campus buildings and learning spaces were selected within Second Life (as a representative of a 3D VLE) for participant students to take short e-learning sessions inside. These spaces represented eleven different variations of each of eight specifically identified architectural characteristics for designing 3D virtual buildings. The chosen characteristics were:

- Building style (e.g. modern, classical)
- Area shape, dimensions & height (e.g. rectangular, circular, dimensions ratio)
- Environmental surrounding elements (e.g. greenery, mountain, sea)
- Seating arrangement (e.g. linear , circular rows)
- Wall design (e.g. wood, stucco, light and dark color finishing)
- Floor design (e.g. marble, carpeting)
- Window design (e.g. bow, gliding windows)
- Interior lighting & open walls percentage (e.g. 50% open walls, 20% open ceiling)

The above mentioned characteristics were specifically chosen because: i) they have been shown to have an impact on student learning in real life physical educational buildings e.g. effect of class size on discipline [7], effect of classroom colors on concentration and performance [8]. This is unlike other features, the impact of which has not been tested on students in the physical world e.g. effect of different column and arch styles. ii) The previous design features and components were also chosen since they exist in 3D virtual environments unlike other building design criteria [9] like for example, ventilation and acoustics control.

The participating sample of students for the study consisted of 65 under graduate and post graduate students from the School of Engineering and Information Sciences at Middlesex University, selected randomly and consenting to partake in the study after explaining the purpose of the research to them.

After engaging the students shortly in each of the previously mentioned 11 “inworld” sites in Second Life, the students were asked to answer the following questions using a seven degree Likert-scale (strongly agree, agree, partially agree, neutral, partially disagree, disagree, and strongly agree) to depict their degree of satisfaction from individual design components in each site and overall satisfaction from it:

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 or point of reference to find the overall average contentment of students from each site as a whole.

The resulting numbers for each question were then multiplied by a factor (weight), described hereafter, and an average satisfaction rate was found for each site, for each category of students (under graduate and post graduate), 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 according to equation (1) below:

$$\Big((\text{no. of strongly agree votes} * 100\%) + (\text{no. of agree votes} * 66\%) + (\text{no. of partially agree votes} * 33\%) + (\text{no. of neutral votes} * 0\%) + (\text{no. of partially disagree votes} * -33\%) + (\text{no. of disagree votes} * -66\%) + (\text{no. of strongly disagree} * -100\%) \Big) \Big/ \text{Total number of participants} * 100 \qquad (1)$$

The positive factors used in the equation above designate student satisfaction, whilst negative factors signify displeasure with the design element, where 100% denotes maximum satisfaction (“strongly agree”), 0% means indifference or “neutral” effect and -100% denotes total discontentment (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 technique was implemented by Chan et al. [10].

Diagrams illustrating the different findings were created accordingly, as demonstrated in the subsequent sections, to show the following:

- Percentage satisfaction scores for undergraduate students versus post graduate students from each architectural element in all presented sites.
- Analogy between average overall satisfaction of all students from each presented site versus all students’ average satisfaction from each individually tested design component in each site.
- Correlation coefficient between overall satisfaction rate from each site and average satisfaction rate from each individual tested architectural element in that site. The

correlation coefficient was calculated according to the following equation (2) [11]:

$$\left(N\Sigma XY - (\Sigma X)(\Sigma Y) \,/\, Sqrt\left([N\Sigma X^2 - (\Sigma X)^2]\,[N\Sigma Y^2 - (\Sigma Y)^2]\right) \right) \qquad (2)$$

where

N = Number of values or elements

ΣXY = Sum of the product of first and second set of values

ΣX = Sum of first set of values (overall satisfaction value)

ΣY = Sum of second set of values (individual element satisfaction value)

$\Sigma X2$ = Sum of square of first set of values

$\Sigma Y2$ = Sum of square of second set of values

3. Results

While the diagrams in the consequent sections show, as part of the findings, which variations of each design element were the most favorable by students or provided most satisfaction, these particular findings were elaborately described by the authors previously [12] and thus are not the main issue here. The main focus within this paper is to analogize

- The rates of response provided by under graduate students compared to post graduate students, in the first section of the results
- The illustrated relationship between the overall satisfaction of students from a 3D virtual learning space in general and satisfaction from its individual design characteristics, in the second section of the results.
- The correlation coefficients between overall satisfaction of students from a 3D learning space and satisfaction from each individually tested architectural feature within this space.

3.1 Analogy between Satisfaction Rates of Under-Graduate and Post-Graduate Students

The subsequent Figures 1 and 2 illustrate the percentage satisfaction of under graduate and post graduate students from the learning space shape and dimensions, building style, environmental features, seating arrangement, wall, floor, window design, and internal lighting as provided by percentage of open walls.

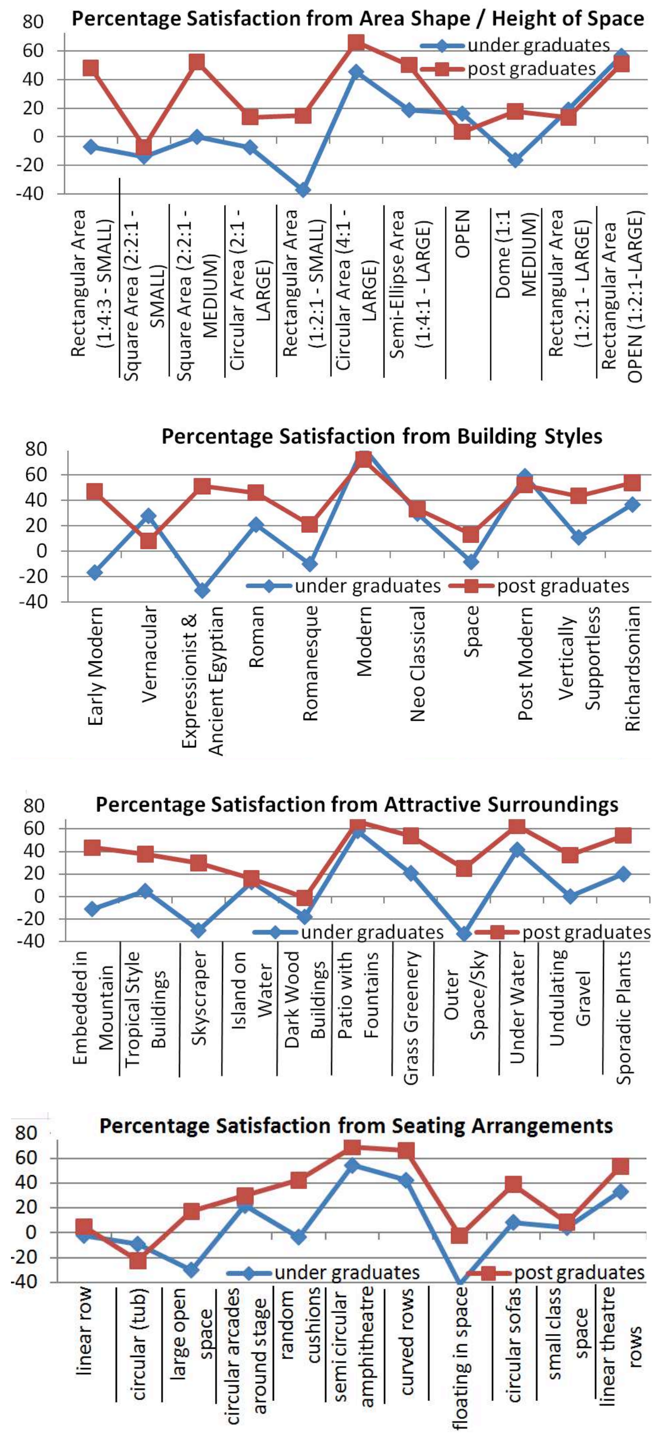

Fig. 1 Percentage satisfaction of under graduate and post graduate students from selected architectural design elements in different 3D virtual learning spaces: i) area shape & height ii) building style iii) environmental features iv) seating arrangement

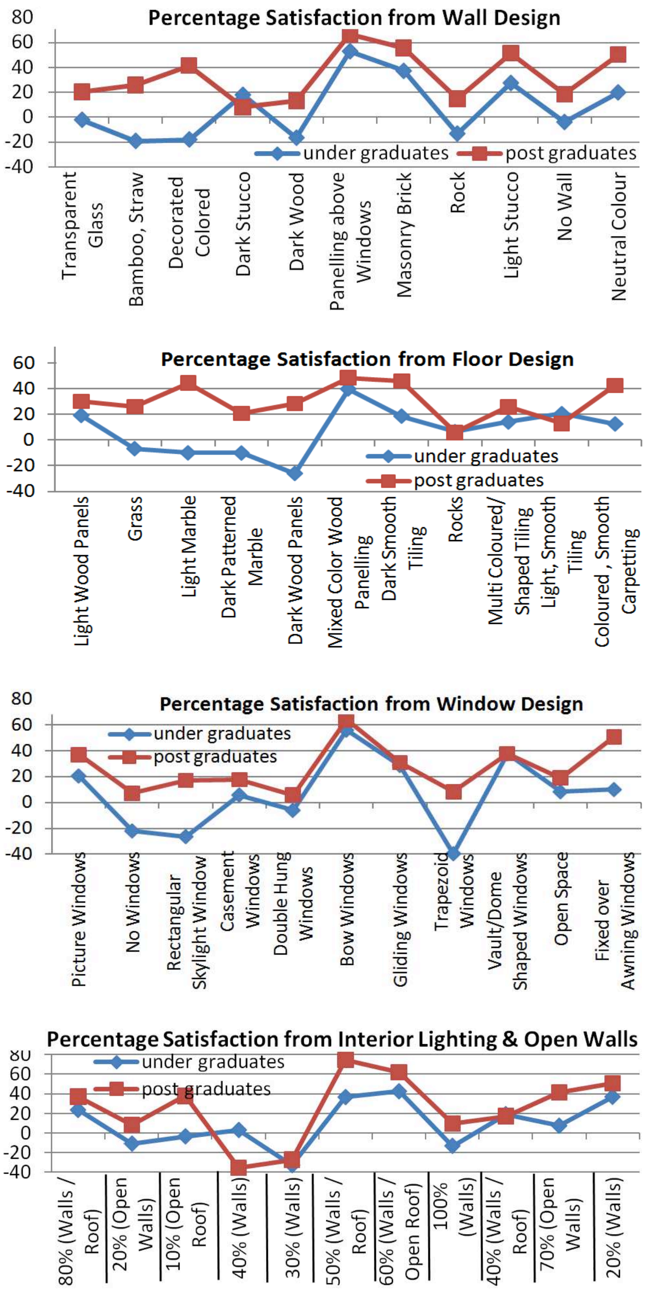

Fig. 2 Percentage satisfaction of under graduate and post graduate students from selected architectural design elements in different 3D virtual learning spaces: i) wall design ii) floor design iii) window design iv) interior lighting and open walls

General findings from the figures above provide evidence for the ensuing results:

- *While there are distinct variations between satisfaction rates of under graduate and post graduate students, the former illustrations show that both groups were always in agreement only over the most preferred variation of each architectural design component tested within this study.*

For example results of both student categories are almost identical for the most preferred building style, i.e. modern and post-modern style. They both also showed a high affection towards presence of landscaped patios with water elements in the surrounding environment and furthermore, underwater themes. In addition, all students expressed most contentment and comfort with semi circular and curved seating arrangements. Even more, the most preferred shape and dimensions of space by both under graduates and post graduates was large circular or rectangular spaces. As for wall and floor design, again results were extremely similar for highest preferences which tended towards light, colored and wood finishing. Bow paneled windows were also highly in favor and presence of approximately 50% of the surface wall and roof area of the space open for interior lighting.

- *Another significant while unexpected finding from the previous figures was the fact that satisfaction of under graduate students from all variations of all design elements in general was almost always less than the satisfaction displayed by the post graduate students for the same variations of the architectural design features.*

This was especially evident with the least preferred variations of each design element. On calculating average percentage satisfaction, of under graduates and post graduates, from each architectural design feature for all sites combined, it was seen that all results for under graduates are significantly less than those for post graduates, as presented by the table below:

Table 1: Overall percentage satisfaction of students from each design feature for all tested sites combined

architectural design feature	under graduate students	post graduate students
building style	11	38
space shape & dimensions	3	29
environmental features	5	38
seating arrangement	1	28
wall design	1	34
floor design	7	30
window design	13	28
internal lighting, open walls	5	27

Implications of the above findings are to be discussed in the subsequent conclusions section.

3.2 Analogy between Average Satisfaction Rates from 3D Virtual Learning Spaces in General and per Architectural Design Element

Another area of focus within this paper is represented by the following Figures 3 and 4. Each diagram depicts a comparison between two measures: i) the average satisfaction of both student categories from each virtual site in general and ii) their combined satisfaction from one of the eight individual design elements tested for in those sites.

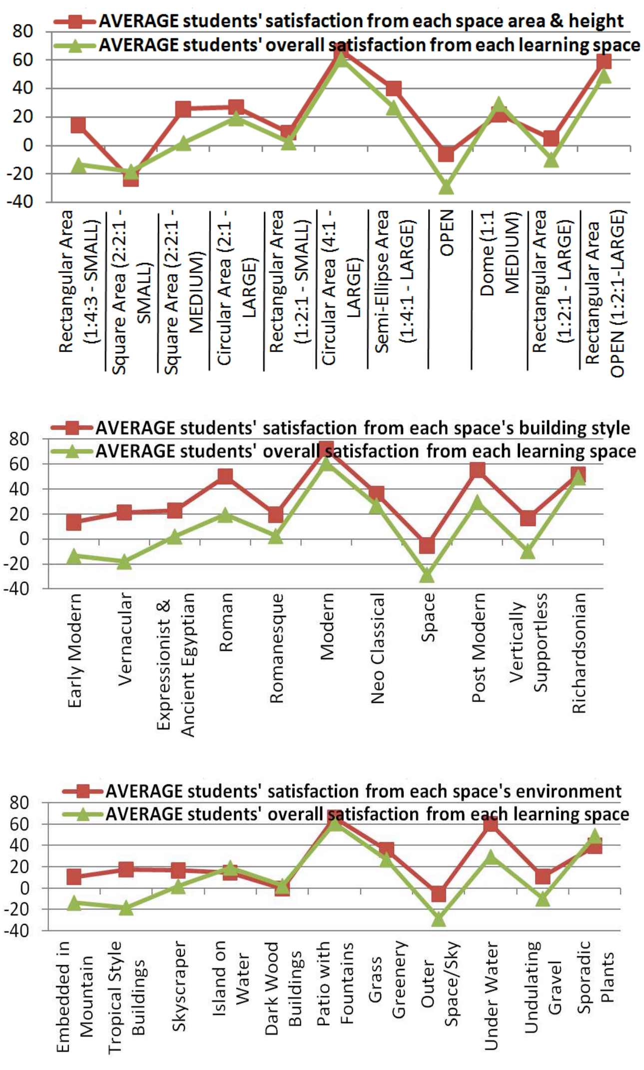

Fig. 3 Percentage satisfaction of all students combined from each 3D virtual learning space in general versus their combined satisfaction from i) space shape, area & height ii) building style iii) environmental features

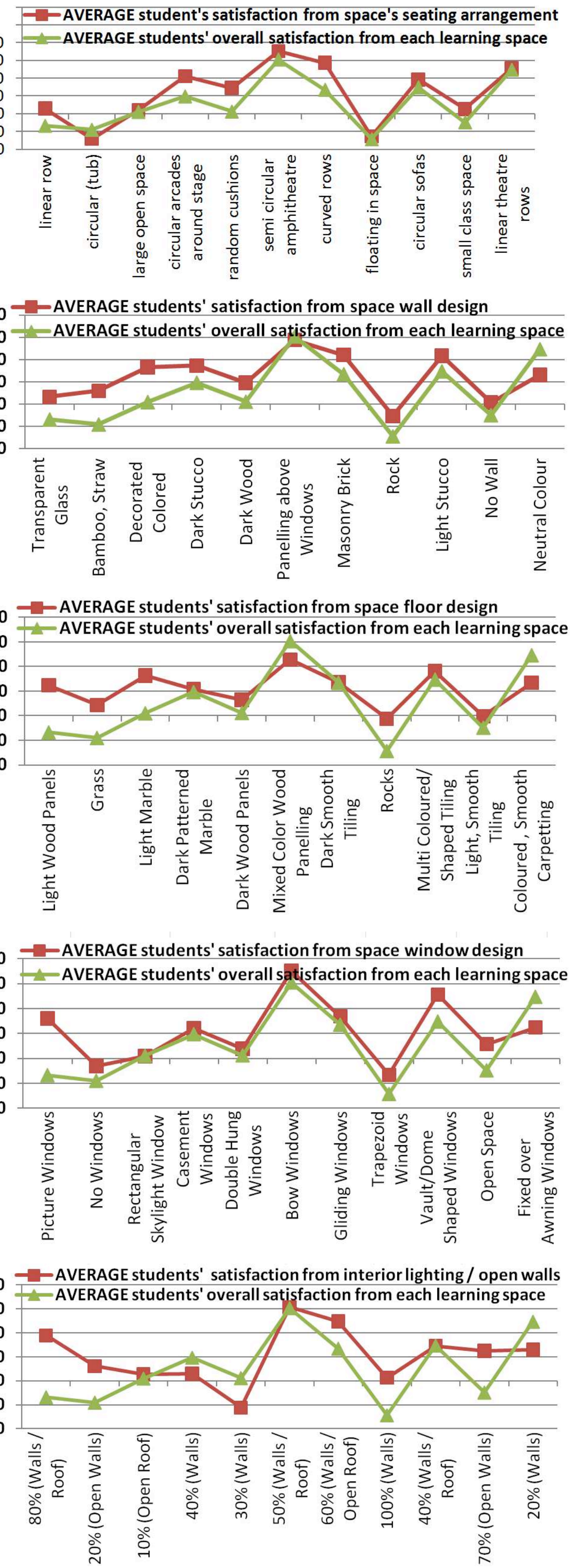

Fig. 4 Percentage satisfaction of all students combined from each 3D virtual learning space in general versus their combined satisfaction from i) seating arrangement ii) wall design iii) floor design iv) space window design v) interior lighting and percentage of open walls

The former figures 3 and 4 offer significant findings regarding the relationship between the overall satisfaction of a student from a 3D virtual learning space and his/her satisfaction from each individual architectural design component in that learning space. It can be clearly deduced that there is a striking similarity in the values and slope gradients between the overall and individual-element satisfaction percentages. This indicates that general satisfaction from a 3D educational space is highly dependent on the architectural characteristics used to design this space and satisfaction from them. This hypothesis is especially supported with the fact that it is applicable for all eight tested architectural design elements within this study, where the recorded overall percentage satisfaction of students from any given site is very similar to the percentage satisfaction from any given design element within that site. To further elucidate this finding and detect if there is a statistical association between the aforementioned factors, a correlation coefficient was calculated between the percentage satisfaction from each individual design component in every site, and the overall satisfaction from that site.

3.3 Correlation between Overall Satisfaction and Satisfaction from Individual Design Features of 3D Virtual Learning Spaces

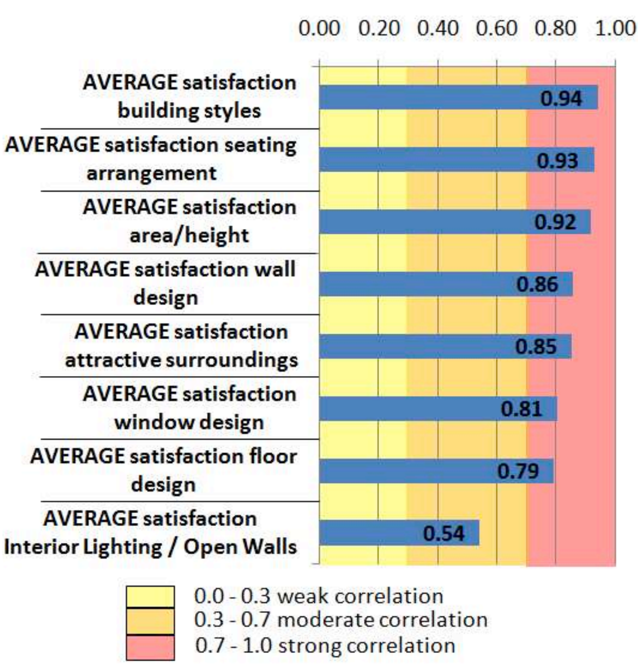

Fig. 4 Correlation coefficient between students' satisfaction from each design element and overall satisfaction from 3D virtual learning spaces

The correlation coefficient is a statistic that represents how closely two variables are related, thus expressing the amount of similarity and dependence between them. It is represented by a number that varies between -1.00 and +1.00 thus quantifying the strength of a linear association between the two variables' range of inputs and outputs [13]. The two variables under inspection within this study are i) overall satisfaction from a 3D virtual learning space ii) satisfaction from an individual design component used in a 3D virtual learning environment. Correlation coefficients between 0.00 and 0.30 signify a weak relationship; those between 0.30 and 0.70 indicate a moderate relationship and coefficients between 0.70 and 1.00 are considered high [11].
Figure 4 noticeably demonstrates that there is a high correlation or relationship between general satisfaction of a student from a 3D learning space and the satisfaction from individual design components of that space. The architectural design characteristics found to have highest association and hence most connection with overall satisfaction from a virtual learning space are the building style of the educational facility, the seating arrangement employed within the space and satisfaction from space shape and dimension ratios. Next in impact are the wall, floor, window designs and how attractive the surrounding environmental features are. However, unpredictably, the student contentment from the amount of interior lighting, represented by the percentage of open walls & ceiling surface area in the space, seems to have least impact on the overall satisfaction of students from their learning spaces. Despite that, the correlation coefficient for this design element is still moderate and thus considerable.

4. Conclusions

This paper aimed at identifying relationships between percentage satisfaction and contentment of different categories of students, and correlations between satisfaction from overall 3D virtual learning spaces and their individual design features. Recognized findings within this study have the following implications:
Only the best perceived variation from each architectural design feature of a 3D virtual site was demonstrated to be identical for both under graduate and post graduate students. This unanimous perception can help create generalized guidelines for design and enhancement of educational facilities in 3D virtual learning environments. These guidelines, which take into consideration best practices for enrichment of a student's online e-learning experience, are currently non-existent as formerly evidenced from literature, and thus it becomes imperative to initiate such a framework of educational facility design.
Another significant conclusion uncovered within the current study shows that overall satisfaction rates provided

by under graduate students are generally lower than those displayed by post graduate students for any given 3D virtual site or its individual design components. This can be attributed to two facts: i) under graduate students may be novice to using 3D worlds as an educational medium compared to post graduate students, and thus are more unfamiliar with their 3D virtual presence inside virtual learning spaces hence rendering them skeptical and less accepting or satisfied with the e-learning experience, its venue and design characteristics if not resembling the physical world classroom which they are accustomed to. ii) On the contrary, undergraduate students may be too exposed to game playing within 3D virtual worlds to the extent of comparing their e-learning venue to the stimulating, constantly changing gaming environment they are used to. This would consequently negatively affect their perceived satisfaction from the 3D learning spaces used in this study. iii) In contrast, post graduate students may be more flexible in accepting new ideas and new environments, hence would show more satisfaction from their 3D virtual learning spaces and their design characteristics than under graduate students.

An additional conclusion attained within this study concerns establishing a relationship and correlation between overall contentment of students from a 3D virtual e-learning site in general, and satisfaction from its individual design features. Since a high correlation coefficient was found for all design features considered in this study, this indicates that a student's pleasure and satisfaction from an educational space is highly dependent and reliant on its architectural design characteristics, especially seven out of eight of the selected characteristics, namely the building style of the educational facility, the seating arrangement employed within the space, space shape and dimension ratios, wall, floor, window designs and surrounding environmental features . Internal lighting denoted by the percentage of open walls & ceiling surface area in the space was also found to have an impact on overall satisfaction from 3D learning spaces, but at a lower level. This conclusion asserts the choice of the architectural design elements selected within this study for testing.

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Biography

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Research interests: Human issues in software engineering, focusing on their effects in software development / Distributed team working as in virtual teams and collaboration across networks / Online communities of practice / e-Business effects on society (e.g. e-portals, electronic employment contracts, privacy and security) / e-Learning focusing on computer-assisted assessment and computer-mediated communication