Analogy between Student Perception of Educational Space Dimensions and Size Perspective in 3D Virtual Worlds versus Physical World

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Abstract

One of the prominent practices currently associated with 3D virtual worlds, such as Second Life, is their increased utilization as 3D virtual learning environments (3D VLEs). This study is part of a research in progress dedicated to evaluate different engineering design aspects of these emergent VLEs, and define the impact of their design features on delivering online education. The aim of this paper is to investigate and analogize between users' perception of space in virtual worlds compared to its corresponding perception in the physical world in terms of area size, dimensions and overall 3D visual perspective. This is achieved by recording the visual estimations of different student categories, within diverse 3D virtual sites, in response to survey questions depicting space size and capacity for holding students and hosting e-learning sessions. Furthermore, the differences in student responses are analyzed and elucidated in order to formulate a hypothesis about how similar or dissimilar users perceive spaces in 3D virtual worlds in comparison with the physical world.

Keywords: visual perception in 3D virtual worlds, virtual learning environments, educational facilities in Second Life, class capacity in e-learning spaces.

1. INTRODUCTION

Since the onset of 3D virtual worlds, whether used for gaming purposes or as learning environments, 3D designers and builders have strived to create virtual constructions within them that have proved to be both innovative and imaginative but also comfortably familiar for the user [1]. This flourishing in 3D virtual design has been the result of the vast disparity between the physical world and virtual worlds in terms of diminished constraints to free design [2], for as previously asserted by Bourdakis and Charitos [3], the nature of space in virtual environments (VEs) is fundamentally different from the nature of real space and thus subsequently the architecture of VEs requires new theory and practice. Examples of these fundamental differences include the non-presence of gravity, material and budget restraints, which have given rise to many known and novel building styles in VEs such as Photo-realistic (identical replica of existing in reality), artistically-realistic (similar to existing in reality), functionally-realistic (has no equivalent in reality but is realistically designed), metaphorically-realistic (entails realistic functions), hybrid (mixture of realistic and imaginative design), fantasy (imaginative design defying reality), and abstract (ambiguous design) [4].

In 3D virtual places, designers are increasingly faced with higher-degree spatial organization than in the physical world, comprising the cognitive relationship between content and space [1]. Cognition is a process proclaimed on the user's sensory-motor and neurological systems. The process of visual acquiring, assimilation and interpretation of environmental information is called cognitive mapping to understand the relationship between the objects in a space [5]. Therefore, since Downs and Stea [6] denote that "human spatial behavior is dependent on the individual's cognitive map of the spatial environment", this indicates that a user's perception of the virtual space within a 3D VE can control his conduct within this virtual environment. This would accordingly also imply that students' perception of their learning spaces in 3D VEs would hence affect their behavior inside them. It is thus the focus of this paper to investigate how students' perception of 3D virtual e-learning spaces differs from their perception of physical learning spaces in an attempt to explore whether this affects their overall learning process. Results of this research can subsequently help educators and designers in VEs to enhance the architectural design of virtual 3D learning spaces in VLEs to be more suitable for students' e-learning within them.

2. BACKGROUND

The effect of physical spaces on students' learning in general has been amply asserted in previous literature. Oladipupo and Oyelade [7] state that "there is more to students' failure than the students' ability". According to Kenchakkanavar and Joshi [8], incompatibility of classrooms for teaching was one of the factors affecting student failures in their courses. Furthermore it has been demonstrated that classes smaller than 900 sq. ft. in area are undesirable as they do not allow for adequate movement between tables without bumping into students and their belongings; crowded classrooms contribute to discipline problems [9]. However if a 900 sq. ft. class is built inside a VE, will the students perceive it as the same size as in the physical world, or smaller or larger, and thus will it be adequate for their needs? Moreover, narrow hallways that are too small for student traffic between classes have been found to encourage fighting and hinder evacuation in emergencies [10]. Again here while corridors of 2m width might be acceptable in the physical world, would this width be perceived as sufficient in the virtual world? It is therefore imperative in the case of 3D virtual learning environments to inquire into how a student identifies with the surrounding spaces, perceives dimensions, shape, and perspective and how that is different from perceiving the totality of spaces in the physical world. This realization is essential since if differences prevail between the virtual and physical worlds in perception of space size, then this necessitates a change in the engineering codes and guidelines used by educators, designers, builders and architects to build inside 3D VLEs to counteract for these differences in perception.

Hence, in agreement with Lau and Maher [1], orienting users within efficiently designed spaces in a virtual environment requires a "detailed study of environmental cognition". Cognition and visualization involve graphic rendering of data in such a way to take advantage of the human ability to recognize patterns and see structures [11]. To understand how these cognitive principles can be applied to the design of VEs, experiments with users, namely students in this study, are required to capture students' different perceptions of the 3D spaces they experience during their e-learning sessions. To pursue this notion, it is necessary to initially differentiate between the different types of user viewpoints available within 3D VLEs. While participants have the capability to observe the environment from many perspectives [12], there are two basic types of perspective viewpoints in 3D VLEs: i) virtual reality perspective and ii) virtual world perspective [13]:

Virtual reality can be defined as an environment created by the computer in which the user feels immersed perceptually and psychologically in the digital environment [14]. The main difference between virtual reality and virtual world viewpoint is the way the user experiences the virtual environment. If the VE is experienced through the first person i.e. seeing the world through the eyes of the avatar and surrounded by the environment, then this is virtual reality [15]. This perspective or viewpoint can be achieved by manipulating camera controls in the VE (or wearing head mounted display devices) and is the closest to "real life" physical perspective. In contrast, virtual world view allows the user to see the VE in 3rd person by watching the avatar move at a distance inside the VE [13]. These differences result in different spatial cognition by the users [16].

The focus of this paper is to investigate the difference in student perception for 3D virtual space size and dimensions, versus the "real-life" physical perception, using the "virtual world" (3rd person) perspective explained beforehand.

3. RESEARCH RATIONALE AND METHODS

The "virtual world" perspective tested in this study is the default viewpoint utilized within 3D VLEs in general and the more commonly used among students for navigation in 3D VLEs. In order to capture the difference between students' perception of space size between the virtual world and the physical world, the subsequent research rationale and techniques were followed:

Several randomized samples of students from different categories (elaborated henceforth) were asked to participate in short consecutive e-learning sessions inside 15 selected 3D virtual learning spaces, inside which students were encouraged to navigate, using the "virtual world" viewpoint, to assimilate the extent of the space size by being immersed inside each (explained henceforth). At the end of the time spent inside each virtual site, the students were all asked to record how many users they perceived this space could hold by choosing from a list of predetermined ranges, also described consequently. Other closed ended questions were asked of the students related to assessing more engineering and architectural design elements of the space, but which are not the focus of this paper at hand. The numerical results offered by the students concerning their perceptions were then averaged for each 3D virtual site used, and these results were compared to the actual number of students that each site would actually hold if built in the physical world with the exact same dimensions. This comparison was used to identify whether space in virtual digitized worlds is recognized by users as being the same size as that in reality or larger or smaller.

The study was conducted in Second Life as a representative of 3D Virtual Learning Environments for its popularity among universities and educational institutions for delivering e-learning [17]. The samples of consenting participants in this study were 84 students from the School of Engineering and Information Sciences at Middlesex University. They were divided into 31 under graduate students, 33 post graduate students, and 20 members of staff representing adult learners. The participants were diverse in gender and cultural background. Results taken from all 3 categories of students were analyzed comparatively and relevant conclusions were drawn accordingly.

The 15 selected 3D virtual learning spaces were chosen to represent a diverse number of variations in space design characteristics in terms of:

- space shape (e.g. circular, rectangle, square)
- size (e.g. small, medium, large – criteria for size naming explained hereafter)
- dimension ratio (width:length:height e.g. 2:2:1)
- openness of space (i.e. whether space is confined by walls or not)

This variety in choice was essential in order to identify if there were any prominent architectural design factors affecting student perception of spaces in 3D VLEs.
The ranges of answers that the students were asked to answer from included:

- space can withstand: 10 - 30 students
- space can withstand: 40 - 60 students
- space can withstand: 70 - 100 students or more

The above three answering criteria were determined based on real-life physical classroom classifications where i) classrooms are considered “small” size learning spaces with capacity up to 28 students. If 2.5 – 3m^2 is required per student, then the average area of a classroom would be 25-75m^2. Educational spaces with similar area size in Second life were used as examples of small learning spaces. ii) Seminar rooms are considered “medium” size learning spaces with capacity of 45-60 students. If 2.2-2.6 m^2 is required per student in a seminar room, then the average area would be 100-150m^2. Educational spaces with similar area size in Second life were used as examples of medium learning spaces. iii) Lecture auditoriums are considered “large” size learning spaces with capacity of up to 200 students. If 1.6-2 m^2 is required per student in a lecture hall, then the average area would be greater than 150m^2. Educational spaces with similar area size in Second life were used as examples of large learning spaces [18] [19]. Learning spaces holding over 100 students were rare in Second Life since the current servers' capabilities cannot withstand more than this number of logged in users at the same time on the same site. Each learning space used within this study was also classified as “open” if it did not contain surrounding walls.

The equation used to calculate the average perceived number of users by students from each category for each site was:

$$\left(\begin{array}{l} \textit{(no. of “10-30” votes * 30) +} \\ \textit{(no. of “40-60” votes * 60) +} \\ \textit{(no. of “70-100” votes * 100)} \end{array} \right) \Big/ \textit{Total number of participants}$$

As an additional analysis, the standard deviation between the results of under graduate students, post graduate students and adult learners was also calculated to find the discrepancy between the values and how this may be related to different types of educational space shapes, sizes and dimensions. The standard deviation measures the spread of the data around the mean value and thus how widely dispersed they are from the maximum to the minimum value. The larger the value of the standard deviation the more this implies that the individual data points are farther from the average value. To calculate the standard deviation, the mean value is first calculated. Next, the deviation of each data point from the average is calculated by subtracting its value from the mean value. Each deviation is squared, and the individual squared deviations are averaged together. The resulting value is known as the variance. Standard deviation is the square root of the variance [20].
Diagrams illustrating the different findings were created accordingly, as demonstrated in the subsequent sections.

4. RESULTS

Results in this paper were identified in three areas in accordance with the aims and focus of this study:

- A comparison between the results obtained from under graduate, post graduate and adult learners concerning their perception of the number of users that each 3D virtual learning space in consideration can withstand.
- An analogy to compare between the overall students' average perceived number of users for each site (and thus what area size is implied for that site) versus the actual number of users that could be withheld if this learning space was built with the exact same dimensions in the physical world.

- Calculate the standard deviation between the results of the three student categories, for each 3D virtual site, to find out factors affecting different perceptions by students.

4.1 Capacity of Users Perceived for each 3D Virtual Learning Space

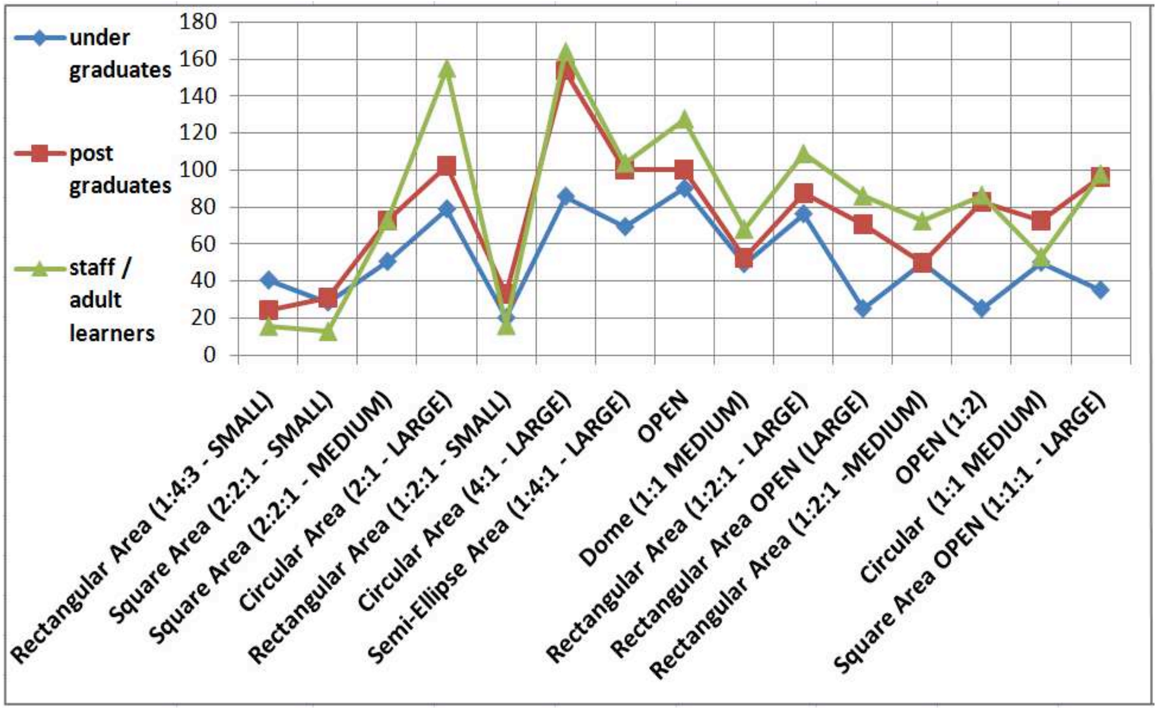

FIGURE 1: Average number of users that can be withheld in each site as perceived by different categories of students

The former Figure 1 illustrates the perceived number of users that each category of students (under graduate, post graduate and adult learners) estimated can be withheld inside each of the 15 3D virtual learning spaces selected for this study.

As evident from the figure, it can be clearly noticed that average number of users perceived by under graduate students for the different sites in general tends to be lower than results depicted by the other two categories of students for all sites. Even more, while demonstrated results for post graduate students are higher than those for under graduate students, they are still lower than those offered by adult learners, who give the highest capacity of students for all sites. This can provide a general trend where the older the age category, the larger the students' perception is of the size of the 3D virtual learning space and the capacity of users it can hold. The implications of these findings are to be discussed in the conclusions.

4.2 Average Perceived Number of Users and Size of each Site compared to the Actual Space Size

The average perceived numbers of users for each site demonstrated in Figure 2 denote the mean values for all three combined categories of students for each 3D virtual site. It can be evidently seen that the students' overall estimation for the number of users withheld in each site (and thus also approximation for the size of the space) is very similar to the actual number and size ranges of each space. Small, medium and large spaces were correctly identified by students by correctly estimating the number of users that should be within each space. This result holds true despite the differences in the learning space shape, dimensions ratio, and openness of walls differentiating the architectural design of the 3D virtual spaces from each other. The implications of this result are to be discussed consequently.

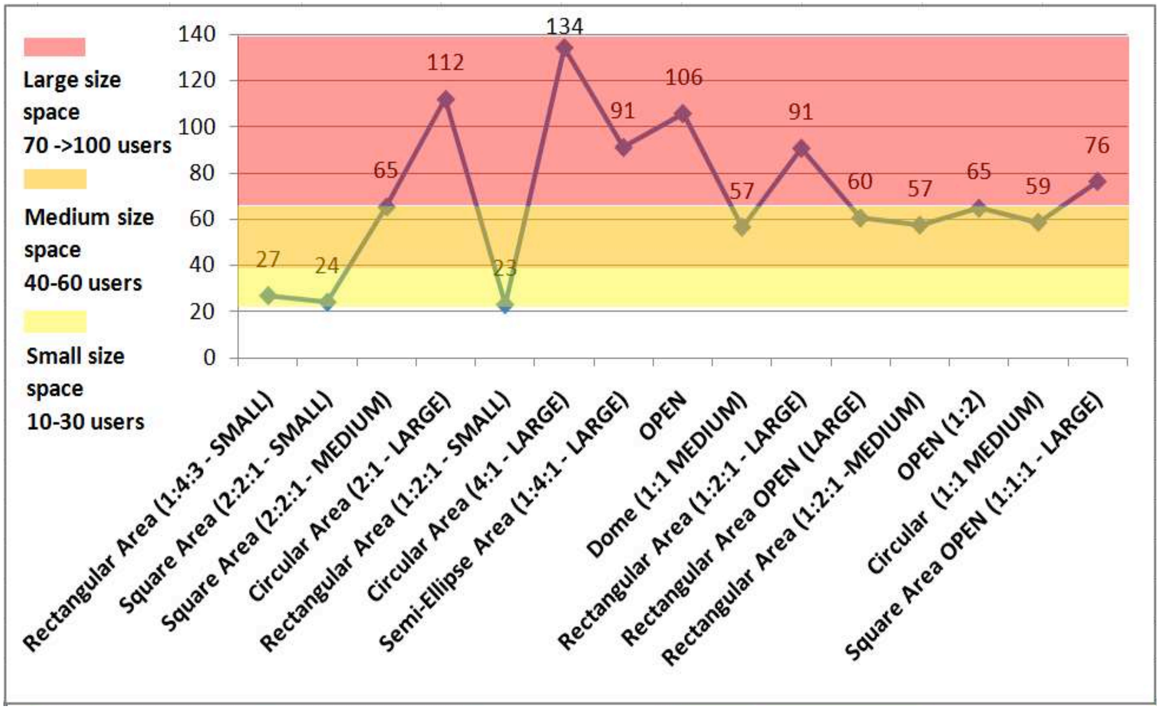

FIGURE 2: Correspondence of number of perceived students per site to the actual capacity and size of each site

4.3 Standard Deviation between the Response Ranges of the Student Categories

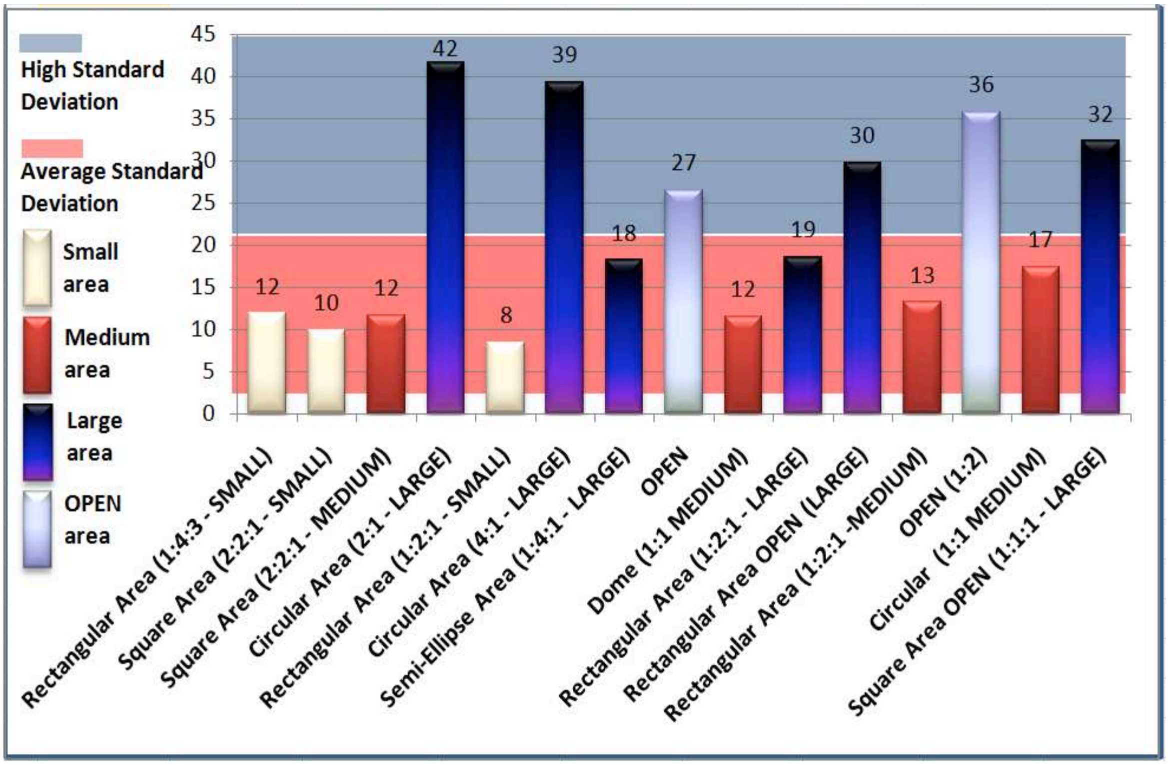

FIGURE 3: Standard deviation calculated between responses of different student categories for each 3D virtual site

Figure 3 displays the calculated standard deviation between the highest and lowest perceived values of number of users given by the 3 student categories for each site. The purpose of this procedure was to find which virtual spaces offered most uncertainty to students and indecisiveness in estimating the number of users that a space can hold. This is because the greater the difference between the numbers offered by the 3 categories of students for each site, the higher the standard deviation, signifying that there are split opinions regarding the number of users that a space can hold, which means increased uncertainty and inability to visually identify the correct size of the space in concern by all students involved. The sites providing this problem were examined to identify any common architectural design factors between them that might be the cause for this difference between the virtual and physical perception.

The results in Figure 3 clearly show that there was an acceptable and moderate deviation in values (presented by the 3 student categories) for all “small” and “medium” sized 3D virtual learning spaces used in this study (- definition of “small”, medium” and “large” clarified earlier). However a very high standard deviation could be seen with “large” sized 3D virtual learning spaces which are either circular in area or “open” spaced with no or few encompassing walls. Completely open venues (e.g. outdoors, space etc.) were also very difficult to estimate numbers of users for, producing the same uncertainty. The only types of “large” sized spaces which gave a moderate deviation of results were those containing straight-linear or curved-linear rows of seating. The implications of all the above results are discussed in the following section.

5. CONCLUSION & FUTURE WORK

Three sets of significant results were obtained from this study that will be elaborated on in this section. The whole study was conducted using the “virtual world” perspective for student navigation explained earlier.

It was initially identified that under graduate students have the tendency to under estimate the size of any given 3D virtual learning space compared to post graduates who offer higher numbers and adult learners who offer highest numbers of perceived students for virtual spaces i.e. perceive the space larger than younger groups of students. This can be attributed to the fact that under graduate students are more acquainted with 3D online gaming environments which offer vast terrains and multitudes of buildings thus might cause any individual learning space to seem smaller in comparison to what students are used to in gaming environments. While adult learners provide higher values for perceived numbers of students than post graduate students (i.e. perceive the space size as larger), both results are close which might indicate that more mature students in general estimate space size more realistically and correctly. These results can be useful for educators, designers, architects or builders in general in VLEs by creating design guidelines for building enhanced educational facilities inside 3D Virtual Learning Environments . One design recommendation in this case would be to enlarge the size of the 3D virtual classrooms and learning spaces more than their counterparts in the physical world so as to appear for undergraduates the same size as the physical spaces (after taking into consideration the diminishing visual perception effect experienced by under graduate students in 3D VLEs), or appear for graduates and adult learners as slightly large and thus more comfortable and spacious to learn inside. This added contentment with the space size would help enhance the student e-learning experience in 3D VLEs.

The second set of results attained within this study is related to how accurately students in general estimated the space sizes and perceived them with the same dimensions as they really are. This was done by estimating the correct number of users that can be withheld in each site. The results showed that all virtual spaces were estimated to be within the correct “small”, “medium” or “large” size ranges (with some discrepancy between the 3 different student categories but within the mentioned size ranges e.g. undergraduates perceived them quite smaller as mentioned earlier). Thus, this indicates that visual perception and interpretation of space size by students in the 3D virtual world in general is very similar to that in the physical world.

The third set of findings, depicting standard deviation between results, shed light on factors which might be attributing to incorrectly understanding and perceiving the 3D virtual space. It was shown that while there were no problems with correctly identifying “small’ and “medium” sized spaces, circular shaped “large” size spaces and open spaces caused most confusion and uncertainty for students when attempting to define space size (through identifying number of users inside it). This may be attributed to the fact that absence of boundaries and set seats made it difficult to recognize space sizes correctly and caused this disparity between virtual conception of space and physical conception of space. An additional building recommendation for 3D virtual educational spaces that can be derived from these results can be to assign more defined and distinct seating arrangements for users within circular shaped and open learning spaces to help students perceive the space perspective more accurately.

Future work can be used to provide further evidence for how students perceive the 3D virtual space by creating customized models in Second Life, subjecting students to them and observing their reactions to changing other engineering and architectural design elements in their surroundings. Investigating change of individual dimensions of the space (e.g. height, width, length) on students’ perception of the space and their satisfaction from it can be also subject to future research.

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