Architectural Evolution of E–Learning Virtual Worlds:
Proposed Design Measures to Enhance the E–Learning Experience within 3D Learning Spaces

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ABSTRACT
Numerous approaches are currently being adopted to efficiently utilize emergent 3D Virtual Worlds (VWs) for delivering e-learning, concentrating mainly on teaching and learning applications. Equally significant, this research demonstrates the importance of customizing architectural design characteristics of 3D virtual learning spaces within these VWs as another complementary and essential user-centered approach to enhancing students’ e-learning experiences. This is achieved by displaying higher education students’ propositions and requirements from the design elements of their 3D educational spaces best suited for promoting their skills, satisfaction and participation during their e-learning sessions. These recommendations can be used by educators and designers to enhance the design features of existing and future 3D virtual educational facilities within 3D VWs to augment the students’ e-learning process.

INTRODUCTION
The fundamental aim of this research is to enhance students’ blended learning experiences comprising of both face-to-face and online courses, by investigating factors and procedures that can help achieve maximum assimilation, achievement and enjoyment from e-learning within 3D Virtual Learning environments (VLEs) such as Second Life. Best practices in 3D pedagogy have essentially entailed development of educational methods, 3D applications and activities to support different learning modes and learning styles of students in 3D VLEs (Calongne, 2008; Scopes & Lesley, 2009). However as Philip Johnson, a renowned architect, believed, “All architecture is shelter, all great architecture is the design of space that contains, cuddles, exalts, or stimulates the persons in that space”. Since one of the vital factors evidenced to have an impact on students’ physical learning in “real-life” is the design characteristics of the learning space (Evans, 1980), elaborated consequently, this research has invested into finding the effect of 3D virtual architectural design of educational spaces on e-learning of students, by capturing learners’ preferences and propositions for design elements to be used in their 3D virtual learning spaces that would augment satisfaction, retention, participation and enjoyment. This would hence allow reaching best user-centered practices in virtual architectural design of 3D educational building spaces, for the benefit of students and supplementing their e-learning experience within virtual worlds. Best practices in delivering practical, effective teaching and learning would therefore be achieved with the help of both i) innovative virtual educational methods and ii) applying most suitable 3D design features to educational spaces during e-learning sessions.
While this study pertains to multiple sectors of students in higher education (namely under-graduate, post
graduate, and adult learners participating within Second Life as a representative of 3D VLEs), findings of
this research are not specific to Second Life only but rather general to 3D Virtual worlds in general since
the psychological impact of the design of a 3D virtual learning space on its users is universal in any
virtual world.

Along with the pedagogical immigration trend of many educational institutions towards 3D VLEs
(Joseph, 2007), arose creative opportunities for erecting buildings that cross the realms of reality and
explore the imagination of the designer. This is because of the fundamental discrepancy between the
physical and the virtual world where there are no restraints on budgets, no engineering natural forces and
material strength limitations, no infrastructure requirements, sound, ventilation regulations or even gravity
which can be disregarded to have 3D virtual buildings floating in midair or immersed under water
(Bridges & Charitos, 1997). Such novel construction techniques have been used to construct virtual
university campuses in 3D VLES to produce a wide variety of designs that range between realistic
portrayals or imitations of physically existing campuses, and completely imaginative embodiments
(Alarifi, 2008).

However there is no academically conducted research that directly associates between the new e-learning
techniques sprouting within 3D VLEs (Saleeb & Dafoulas, 2010a), and the architectural design
specifications of the 3D virtual spaces within which this e-learning is taking place (Minocha & Mount,
2009), and thus whether these design specifications have an impact on the effectiveness of e-learning on
student users of 3D VLEs (Saleeb & Dafoulas, 2010c). Such design features include color, texture,
dimensions of space, lighting, and ventilation amongst others. Even more, 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 fulfillment and comfort towards it (Saleeb & Dafoulas, 2010b). The current research thus initiates
closure of this gap by capturing students’ design suggestions and proposals to achieve satisfaction and
contentment from architectural design elements of virtual educational buildings within 3DVLEs, hence
giving the opportunity to issue recommendations for future learning space enhancement: the technique
used for data collection explained hereafter.

This study offers insights in preliminary stages for defining the effect of environmental factors on a
student’s e-learning experience within 3D Virtual Learning Environments, and provides opportunities for
further developing the ‘Supporting Teaching and Learning’ strand of activities. More specifically the use
of 3D VLEs could address issues relating to (i) learning & technology, (ii) Open Educational Resources
and (iii) inclusion.

BACKGROUND

Previous literature indicates that, in the physical environment, characteristics such as color, dimensions,
shape, textures, ventilation, sound, lighting and other factors of the physical learning space affect the
degree of achievement and assimilation of students from education within these spaces. For example it
has been established that classes smaller than 900 sq. ft. in area do not allow for adequate movement
between tables without bumping into students and their belongings; crowded classrooms contribute to
disciplinary problems (Eberhard, 2008). The Ohio University Facilities Commission also noted that
students participated twice as much in discussions in classrooms with warm colors, soft furniture, and
textured floor coverings. Students rated these classrooms higher than traditional classrooms. Another
study found soft colored classrooms associated with better attendance and positive attitudes toward class,
instructor and classmates, while an "ugly" environment gives feelings of discontent, the desire to escape,
and fatigue. Light (especially natural) has been shown to affect blood pressure, pulse, respiration rates,
and brain activity. Exposure to full-spectrum lighting is associated with better attendance, more positive
moods, great concentration, and better scholastic performance (Fink, 2002). On a separate note, narrow
hallways, that are too small for student traffic between classes, have been found to encourage fighting and hinder evacuation in emergencies (Hall, 2001).

However, as stated earlier, the analogous effects of learning space architectural and environmental design characteristics in 3D virtual worlds on students’ e-learning are currently under-researched. One of the scarce studies relating to this topic conducted by an individual market research, within Second Life, depicting users’ reactions to preferences between realistic buildings and imaginative style buildings, only reveals that users prefer realistic style buildings with a percentage of 60% more than imaginative style 3D buildings (Market Truths, 2007; 2009). Furthermore, there are no devised building codes for designing 3D virtual educational facilities, analogous to those available for building physical educational facilities. There are only some general recommendations or guidelines offered by previous researchers interested in design of virtual environments, based on observation and interviews (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) suggested using architectural and environmental elements such as landmarks, signs, 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 open spaces (but with no detailed specifications provided) (Charitos, 1998). Bridges & Charitos (1997) noted 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). Minocha & Reeves (2009) further proposed 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 and participation experienced by the learners, only pedagogical factors were identified not architectural factors (Minocha & Mount, 2009). A research on user orientation within 3D VLEs conducted by Charitos (1999) shows 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 with one dimension more than 2 or 3 times the other dimensions induces movement towards the elongated direction (Charitos, 2005).

As noted by Drettakis et al. (2007), while the current state of VLE maturity is developing its techniques to support multiple tasks, it is rare to find complete VLEs that attain both a high-quality realistic, immersive real-time environment and the level of interactivity required to carry out adequately intricate real-world tasks, e.g. teaching and learning. Appleton and Lovett (2005) further elaborate that, contrary to expected, a high level of realistic details renders a space unbelievable or unconvincing for users. Mixing abstract and realistic data is hence more beneficial to prevent “information-overload” for the users, because insignificant details are left out and a clearer view is established. Furthermore, this is anticipated to improve user engagement, because the mix of abstract and realistic data stimulates creative thinking, i.e. both right-brained-mode and left-brained-mode are stimulated in the thought process. The addition of view-dependent texturing of objects in VLEs, realistic vegetation, 3D sound, shadows and consistent lighting, all contribute to an increased sensation of realism and immersion enabling better perception of space and physical objects as well as the sense of scale (deBoer et al., 2009). For example, smaller trees conveyed a sense of being “hotter” than that with large trees and larger shadows (Drettakis et al. 2009). Together with student interactivity, all of the prior mentioned elements can augment users’ capacity to learn.

COINING A NEW FIELD
As evident from preceding literature, 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. 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. Thus as can be seen, 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, without taking into consideration how this affects the learning of students in this space. Or at best practices, 3D virtual learning spaces are being designed in accordance with real-life physical architectural conventions for building such spaces, not knowing whether or not these same design conventions are suitable in virtual worlds for the e-learning experience of a student (Saleeb & Dafoulas, 2010d).

The authors have accordingly found it imperative to coin or establish a new field term to address the above research area, namely “Architectural Evolution of E-learning Virtual Worlds”.

This evolution requires the cooperation of all stake-holders within these virtual worlds and environments to occur. For example, as affirmed by Swan et al. (2003), involving users and designers from the beginning in the process of design and evaluation of VLEs, improves the effectiveness of the VE: hence the importance of capturing students’ design suggestions and propositions strategy as employed by the authors within this study. Furthermore, Sowizral et al. (1995) indicate that to work effectively in a virtual environment (VE), the application content must include the ability to access or change environmental/system/meta parameters, create and manipulate particular objects, perform analyses, and export changes to permanent storage. Also detailed user requirements analysis with architects and urban planners can confirm the suitability of choice and lead to a thorough study of these domains (Roussou et al. 2004). Ultimately a key element would be the establishment of a close collaboration with the end-users.

This was done within this research by subjecting different groups of student participants to different 3D sites in Second Life containing diverse variations of a multitude of architectural design characteristics. The evaluation instruments included direct observation of students, think-aloud protocol and post-experimental questionnaires (Ericsson & Simon, 1985). Subjects were consequently asked to reflect on best and worst perceived characteristics, and asked to suggest design features that they would prefer to be used in their customized learning space as elaborated subsequently.

**RESEARCH RATIONALE**

A qualitative research approach comprising preliminary surveys, focus groups and interviews was identified as suitable (Johnson & Christensen, 2004) to discover students’ preferences regarding presence of different environmental and architectural elements within 16 selectively chosen 3D university virtual campuses within Second Life. Partaking in this study were 84 participants from the school of Engineering in Middlesex University, UK. These were divided into the following categories which correspond to the different clusters of learners utilising 3D virtual university campuses to participate in online e-learning sessions.

The participants comprised 31 undergraduate students, 33 postgraduate students, and 20 members of faculty – adult learners - from different age groups (30 to 60 years old). The selected 3D virtual campuses were nominated since they represent a variety of building design specifications with regard to architectural style (e.g. modern, baroque etc.), dimensions of learning space and their ratios, shape of learning space (e.g. circular, rectangular), seating arrangements (e.g. curved, linear rows etc.), window
styles (e.g. arched, bow etc.) and percentage of open walls for lighting, wall floor and ceiling finishing (e.g. wood, marble etc.), and environmental elements surrounding the learning space (e.g. fountains, underwater etc.). The participants were first “teleported inworld” to each of the chosen 16 3D virtual university campuses, and asked to talk about their reactions, opinions and feelings while navigating interactively for 5 minutes in each site (using think-aloud protocol). Participants were furthermore asked to use different viewpoints during navigation i.e. 1st person view (where the user sees the world through the eyes of the avatar), and 3rd person view (where the user follows the avatar’s movement “inworld”). 3rd person view also includes 3 identified perspectives as identified by Leigh et al. (1996): the “mortal” (ground-level) viewpoint, the “deity” (global above-ground while flying) viewpoint, and “balcony” (elevated view – recognized as most popular), any of which users can assume in order to interact collaboratively with a virtual environment. These navigational sessions were observed and recorded by a facilitator for later analysis of factors adding to student satisfaction within these learning spaces (Ericsson & Simon, 1985). A questionnaire consisting of 10 open ended questions was then answered to capture student’s preferences for educational space design, from each of the 16 3D campuses shown to them. Prior to conducting the surveys, the aim of the project was explained to students from several classes, and only those volunteering to contribute remained in the survey sessions, producing the participant numbers mentioned above. As for faculty (adult learners), each member was invited in person to participate, and volunteers were assigned dates and times at their convenience to conduct the survey. The open ended questions used were:

- What interior design aspects did you like most in this learning space?
- How did they make you feel (optional)?
- What interior design aspects did you dislike in this learning space?
- How did they make you feel (optional)?
- What exterior design aspects did you like most in this learning space?
- How did they make you feel (optional)?
- What exterior design aspects did you dislike in this learning space?
- How did they make you feel (optional)?
- What interior design features would you recommend for this learning space?
- What exterior design features would you recommend for this learning space?

The open ended questions were used to allow students to think freely with no inhibitions on their desires, thus opening up points for discussion that the researchers might have overlooked and not specifically asked about or anticipated. After collection and analysis of the preliminary data from the open ended answers, 2 focus groups were arranged (Kontio et al., 2004) with 8 members from each of our 2 undergraduate and postgraduate groups of previous participants, and 5 individual interviews were arranged with members of contributing staff (Guest et al. 2006). These numbers comprised quarter of the whole survey sample, allowing us to discuss in more detail, the users’ perceptions of appropriate architectural design elements for learning spaces, which they proposed earlier.

The following guidelines were used to conduct focus groups, as recommended by Nielsen (1997):
- Each group contained between 6-12 members (smaller groups can be controlled by some of the members, and larger groups can lose concentration)
- Each session lasted around 60 minutes
- Results were recorded by manual note-taking
- Participants were pre-informed of goals
- 5-6 major open-ended questions were prepared for discussion to allow participants to contribute their opinions freely, with flexibility in the questions according to outcome.
- Individuals were chosen who are highly representative of the total population
• Both authors were present as evaluators: one to ask the questions and the other to record conversation and observations of group behaviour.
• Questions were started with an “ice-breaker” e.g. introductions.
• Questions were clear, easily understandable and not directive or indicative of a particular answer.
• A summary of major discussed points was given to participants at the end.

The interviews conducted within this research, with members of educational staff, used the “Interview Guide Approach”. This was a structured method, with a prepared protocol listing the open-ended questions used above and which were to be discussed in more detail with the interviewees. However the questions were asked in random order and their wording was sometimes changed to adapt to the current situation with the interviewee. This was done to achieve flexibility, but at the same to eliminate any effect on the participants’ answers due to ordering the questions in a particular manner. The objectives of the interview were reached through answering the main ideas behind the required open-ended questions even if their diction was adjusted (Johnson & Christensen, 2006).

The different approaches followed in data collection between student sampling focus groups and staff interviews, allowed the authors a more comprehensive understanding of how the two groups would perceive the environment differently. Although student participants were initially approached in groupings who would experience the 16 environments, at the same time the research team ensured that each individual was engaged in one-to-one brief discussions while answering the open ended questions. The objective of this technique was to ensure that the purpose of each question was clear and establishing that the interpretation of the participant responses was accurate.

It became evident that a key difference between student and staff approaches to questions was due to their different agendas while engaging with the environments. Students approached the exercise keen to share their ideas of what a learning space should look and feel like. It was obvious that their drive was to share their views for design principles that should be followed during the creation of their own space in the future. On the other hand staff members, while also learners in their own respect, were motivated to also reflect on how what was shown could affect the delivery of certain learning activities or support academic related and administrative tasks.

Data collected using survey, interview and focus group techniques was then analyzed and categorized into groups of architectural design element recommendations, as detailed consequently, to demonstrate students’ perception of the visual qualities of the spaces, and preferences for a better learning environment.

DISCUSSION OF RESULTS
The results obtained from the questionnaires and transcribed from the focus groups and interviews were matched and compared. The resulting propositions offered by the 3 named categories of students (under graduates, post graduates and adult learners – staff), to enhance the interior and exterior design of learning spaces within 3D VLE university campuses, were defined as over 100 design features that were consequently grouped into 11 major categories, as follows:

• The architectural style (e.g. modern, classic, gothic) and shape of the building (e.g. circular, square, use of columns etc.)
• Wall design, finishing and colours
• External environment elements of design
• Seating arrangements and shapes
• Window styles, shapes and lighting intensity
• Internal space design factors (e.g. dimensions)
These categories represent the foremost design features of a 3D virtual educational building that are of interest to the student or teacher within a 3D VLE to provide satisfaction and contentment during an e-learning session within that space. It was made clear to all participants that the aim of this research was not to focus on just a specific number of design features of the educational facilities, so as not to limit the scope of the research outcomes. The reason is that after identifying design features that could be grouped according to the previously defined categories, the ultimate objective would be to map out the effects of such features on the learning experience of participants, with emphasis on investigating how such innovative environments would contribute to the transformation of e-learning supportive technologies. The following figures represent the average findings for all participants within this study.

**Student Recommendations for Architectural Style**

Figure 1. Number of votes for Architectural Style features of a 3D virtual learning space proposed by

i) all students ii) different categories of students

Figure 1 above illustrates the architectural design style characteristics proposed or requested by students, overall and from each individual group, to be present in their ideal 3D virtual learning space. As evident, these propositions are divided into 20 features with a total of 97 votes, indicating a high significance for this factor on student satisfaction from the virtual learning space. The highest achieving propositions were those related to using modernistic styles with few details and more realistic than imaginative or futuristic designs i.e. similar to “real life” buildings; whilst using ornate, classical architectural styles with abundant details were generally less in demand along with unfamiliar industrial or mechanical styles with angular or blocky protrusions. There were also some suggestions to use organic and fluid design lines with no merge between opposing styles e.g. modern and classic. All of the previous suggestions coincide with literature findings mentioned earlier (Appleton and Lovett 2005) enforcing user preferences in 3D virtual spaces for simple plain designs that depict the physical world. According to discussions during focus groups and interviews, this can be attributed to the fact that this creates a more familiar environment for the students to work in similar to what they are used to in “real-life”, in addition to the elimination of distraction that can be aggravated by using too many details in designing the 3D builds. Further proof of the latter can be seen through requesting Doric style instead of Corinthian style columns which are more elaborate in detail.

Figure 1 also demonstrates that while all student categories are consistent in preferring modern, realistic styles, there is a clear discrepancy between the number of votes provided by undergraduates and the other two groups who show more enthusiasm towards suggesting architectural style propositions, which is a fact discussed consequently.

**Student Recommendations for Environmental Features**

Figure 2. Number of votes for Environmental features of a 3D virtual learning space proposed by
Figure 2 illustrates the importance of the surrounding environmental design elements of the 3D virtual learning space on student satisfaction. One of the 2 highest recommended features was abundance of adjoining greenery, plants, flowers, and trees etc., which according to individual discussions are most preferred to be seen through large windows in the surroundings, not inside the learning space so as not to cause distraction. This is the only feature that all student groups agreed upon in equal high amounts of votes stressing the significance of this feature in student contentment during e-learning sessions. The other overall highly achieving feature, particularly from post graduates, was presence of the 3D virtual learning space underwater. This was an unexpected result especially since it is alien to the concept of “realism” established as preferred by students in the previous section. However on further discussions with students, and also as shown in Figure 2, some students objected to this notion as this increases feelings of discomfort, claustrophobia and even suffocation from the virtual sense of being underwater. Presence of water elements, such as fountains, pools, waterfalls and surrounding sea, were also recommended. Some students also expressed preference for wide open areas and patios between buildings. However, during interviews, some members of staff (adult learners) expressed their apprehension towards using excessive amounts of large trees which can obstruct sight during navigation especially if the user is not proficient using the “inworld” camera controls, and which also cause lag due to high rendering demand on the online connection.

**Student Recommendations for Window / Lighting Features**

![INSERT FIGURE_THREE a & b HERE]

Figure 3. Number of votes for Window and Lighting Design features of a 3D virtual learning space proposed by i) all students ii) different categories of students

The highest voted feature, for lighting and windows design of 3D virtual learning spaces in Figure 3, was presence of strong internal lighting and extensive use of glass windows. Even though there is no natural lighting in 3D virtual environments, according to discussions, students indicated that utilizing large window areas can induce this feeling of enhanced natural lighting. However students, especially post graduates and adult learners, were in opposition of removing surrounding boundaries of a space completely or even just the walls and leaving the ceiling intact but supportless. According to individual dialogues, students expressed feelings of insecurity in presence of supportless ceilings, and also refrained from being entirely exposed to the outdoors during e-learning so as not to be distracted by the surroundings. This is consistent with prior findings by the authors (Saleeb & Dafoulas, 2010e) depicting preference of students for a range of 50-60% of open walls and ceiling in the surrounding surface area of the virtual learning space. Other recommendations for window types include using round, arched windows and fixed panel windows since using panels has no significance in 3D VWs due to non presence of ventilation, and also since panels can be created as “phantom”, i.e. penetratable for users to fly through which eases navigation to class, as indicated in Figure 3.

It is again evident from Figure 3 that under graduates provided the least number of overall propositions which might be due to intimidation and disorientation from being new at using the 3D VLEs technology for their e-learning sessions.

**Student Recommendations for Floor Design**

![INSERT FIGURE_FOUR a & b HERE]
The most prominent recommendations for floor design offered by students, according to Figure 4, were usage of wood as a finishing material but not darker shades of it. Carpet flooring was also in demand; however there was a considerable variation between the different student groups in favor of each finishing material except for usage of wood, on which they all approved. There were also some suggestions for usage of tiled floors but not rock and gravel. According to the focus group and interview results, utilization of the latter finishing materials added to the roughness and ruggedness of the space which is not the best design for educational spaces. There was also a conflict around presence of floating floors. Apparently post graduates were most in favor of them, hence showing flexibility and desire for innovation maybe since they are more adept at using 3D VLEs and thus open to trying more novel imaginative experiences that are not possible in “real life” educational spaces.

**Student Recommendations for Wall Design**

The number of propositions provided for wall design features, as evident from Figure 5, was almost double those suggested for floor and roof design. This can be attributed to the fact that one of the elements of space most seen directly at student’s eye level are the walls, thus having the most impact on them and therefore demanded most; whilst floors, ceilings and seats are below and above direct eye perspective, hence perceived and required less by students. Results confirm that light, bright and even neutral finishing colors with no dark hues are the mostly recommended features. Also, in accordance with results from previous sections, students expressed their disagreeability with ornate details in walls. Again here in accordance with previous results, there was a requirement for half open, half closed walls not entirely open space. Regarding usage of specific finishing materials, wood, brick and masonry (outdoors) were indicated as accepted choices unlike concrete. As for colors, red was contraindicated, corresponding with findings from Wilder (2008) reporting that red causes emotional arousal and can have an innerving effect on users of a physical space. Presence of customizable walls was also a recommendation for 3D virtual walls.

Consistent with previous figures, it is noticeable that, while in accordance with results from other student groups, under graduates provided the least number of propositions for wall design enhancement.

**Student Recommendations for Roof / Ceiling Design**

Figure 6 illustrates student preferences for enhancement of ceiling design for 3D virtual learning spaces. The most required feature was concerned with creating low height buildings. Students were hence divided between their preference for open or retractable roofs, and closed ceilings, even though post graduates seemed to favor closure. Those in favor of open ceilings commented during discussion that this augments
their feeling of brightness and strong lighting in the atmosphere. On the contrary, others remarked that open ceilings made them uncomfortable or insecure due to feeling of exposure to the atmosphere which psychologically relates them to physical spaces under adverse weather conditions e.g. rain or snow. It can be concluded that this fact probably differs from one user to the other according to the “real life” location in which each individual student lives in the physical world. Large ceiling heights were also commendable. As explained during discussion, this helps avatars fly and eases use of the camera controls “inworld”. Lastly dome and vault shaped roofs were proposed as an agreeable form and shape for the virtual learning space ceiling.

There was a considerable discrepancy in votes between the 3 student groups with regards preferred floor design features, indicating an expected diversity in personal taste between them.

**Student Recommendations for Seating Arrangements**

![Figure 7. Number of votes for Seating Arrangements within a 3D virtual learning space proposed by i) all students ii) different categories of students](image)

As evident from Figure 7, the most preferred seating arrangements were either using semi circular or circular rows. Students, with the exception of under graduates, also showed fondness towards using a more comfortable or leisurely arrangement e.g. in the form of pool and random seating. Employing stepped curbs or open floor space for seating, i.e. with no designated individual seats, was unfavored. As for the design style, non wooden seats with backs and sofas were considered as agreeable, with refraining from using floating seats which add to the students’ sense of instability or insecurity while floating in air. Position of the instructor was suggested to be either at the centre of the circular rows or in front of the seating rows in case of square shaped spaces.

**Student Recommendations for Space Design**

![Figure 8. Number of votes for Space Design features of a 3D virtual learning space proposed by i) all students ii) different categories of students](image)

Recommending features for enhancement of the overall space in 3D educational facilities, as shown in Figure 8, indicates a difference between student perception of virtual space and physical space. This is because while many of the Second Life educational sites, visited by participants of this study, were created according to architectural guidelines used in the physical environment as stated earlier, students still commented that they perceived the dimensions of the virtual learning spaces as small, crowded and in need of more enlargement and spaciousness, even though the exact same dimensions in the physical world would be considered as ideal for classrooms and lecture halls. Additional student propositions enforce the need to avoid learning in outdoor virtual spaces to eliminate distraction. Furthermore, while using rectangular shaped spaces were commended, long rectangular proportions between width and length of the space were discouraged so as not to resemble corridor ratio dimensions which, according to Charitos (2005), imposes movement in the elongated direction hence can disturb the e-learning process.

It is worthwhile noting that all student groups were almost in agreement regarding importance of each suggested design feature in Figure 8, with under graduates providing a slightly less number of votes than
post graduates and adult learners. This emphasizes the significance of space design features for contentment of students and enhancement of the e-learning experience within 3D virtual learning spaces.

**Student Recommendations for Entrance Design**

![Insert Figure Nine a & b Here]

*Figure 9. Number of votes for Entrance Design features of a 3D virtual learning space proposed by i) all students ii) different categories of students*

Figure 9 illustrates architectural propositions for improvement of 3D virtual educational facility entrance design. Students highly recommended creating wider entrances than those created using “real life” design code specifications, preferably with no doors or open door panels (so as not to obstruct navigation of avatars), and with as few entrance steps as possible. Furthermore discussion revealed preference for presence of ramps where possible instead of entrance steps to virtual buildings for better accessibility especially for avatars who prefer using wheelchairs “in-world”. More than one entrance to the building was also suggested to be an asset. Moreover students commended having advertisement or bulletin boards beside the building entrance as guide for new students who are not familiar with the virtual space.

Unlike the previous figures, under graduate students provided most votes for entrance design features compared with post graduate and adult learners, which implies the importance of this design element for novice users to 3D virtual learning environments, especially for wayfinding, ease of locating navigational directions and landmarks to familiarize new students with the 3D virtual space.

**Student Recommendations for Space Circulation Design**

Features demonstrated in Figure 10 below complement those in the prior Figure 9 by suggesting propositions for enhancement of the circulation to, from and within the virtual learning space. For example in order to ease navigation on winding stairways, not too many steps should be added per flight, and large dimensions for flight width should be used to be more accessible especially for novice users still struggling with navigation skills. Further discussions revealed the need for banisters on stair flights to prevent avatars from falling off during ascent and descent. This is in addition to the non – popularity of using many winding flights for a staircase. Instead navigation can be relieved using instant “teleporting” stations to transfer avatars instantaneously between floors or rooms, and use of easily accessible and open elevators. Reduction of vertical navigation was also an agreeable notion among students.

![Insert Figure Ten a & b Here]

*Figure 10. Number of votes for Circulation Design features of a 3D virtual learning space proposed by i) all students ii) different categories of students*

While all the previous features were almost voted for equally by students, special fondness was given for flying to class by entering through windows. According to student elaborations, this would entail creating large penetratable window areas. However this feature attained no recognition from under graduate students which again may be attributed to their cautious nature as new users, as opposed to post graduates and adult learners who are more flexible in trying innovative ideas only possible within virtual worlds not the physical world.
TOTAL NUMBER OF VOTES & STANDARD DEVIATION PERCENTAGE BETWEEN STUDENT CATEGORIES PER DESIGN ELEMENT

Figure 11 below compares between overall number of votes provided by each group of students (under graduates, post graduates and adult learners) for each category of architectural recommendations for 3D virtual learning space design. Along the same vein, the standard deviation between the numbers of votes provided by each student group for each design category was also calculated to determine the variation or discrepancy between the results for each design category. The lower the standard deviation, the more the similarity between the numbers of votes provided by each student group, hence implying that the significance of a design category for each student group is similar to the significance for the other groups.

Standard deviation measures spread of data around the mean value and thus how widely dispersed they are from maximum to minimum value. To calculate standard deviation, the mean value of votes per category is first calculated. Next, the deviation of each group votes from the average is calculated by finding the difference between them. Each deviation is squared, and the individual squared deviations are averaged together; this value is the variance. Standard deviation is the square root of the variance (Stanley, 2010).

() [INSERT FIGURE_ELEVEN a & b HERE]

Figure 11. Comparison and standard deviation between numbers of votes for design features of a 3D virtual learning space proposed by different categories of students

The bar lines in Figure 11 emphasize previous results depicting the low percentage of participation in voting by the under graduates compared to the post graduates and adult learners, with the exception of the entrance design features where under graduates’ participation is very high compared to the other groups. This divergence directly affected the values obtained for standard deviation. Least standard deviation was found with the environmental features category indicating a similarity in number of votes and hence significance of this design category for all students. This was followed by window design and wall, roof and floor design categories. A larger deviation difference was recorded for architectural style, space and circulation categories, which are evidently of most consequence to the adult learner students followed by the post graduates. This may be due to the fact that as students become more familiar and comfortable with the environment, their attention becomes increasingly directed towards the surroundings and how they would prefer it to be. The highest standard deviation was found for the entrance design category, which as elaborated earlier was of great interest for under graduate students possibly due to difficulties they might be facing with navigation, directions and orientation of the space on first arriving “inworld”.

FUTURE RESEARCH

Findings within this research are essential in providing preliminary guidelines for enhancement of the architectural design of 3D virtual learning environments to augment students’ e-learning experiences. Further research involves conducting experiments to investigate the effects of individual architectural design components on students’ retention rates, participation rates and enjoyment during e-learning sessions. Further work is also underway to establish best design practices for 3D VLEs to support students of different disciplinary fields of study, gender and culture in addition to different age groups. An essential strategy for triangulation of the aspired data entails conducting interviews with 3D VLE designers and architects to capture their design attempts to address learning needs in such environments.

CONCLUSION
As evident from prior findings within this study, some design preferences of students in the virtual world were similar to those in the physical world adding to the notion of realism in design of 3D virtual educational spaces and desire for emulating the “real-life” learning environment for comfort and contentment during e-learning sessions. The most prominent requirements involved usage of plain architectural styles with spacious non-elongated dimensions, light bright finishing, semi-circular seating arrangements and plentiful lighting through usage of intensive areas of windows. Moreover was the need for external vegetation, wide corridors and entrances, and usage of as little navigational means as possible e.g. stairways.

Data analysis focused on in this study involved comparing results attained from the identified three groups of learners, subsequently to examine the impact that this might have on a student’s learning experience. The total number of votes provided by all students for all propositions, for enhancement of 3D virtual learning spaces, was 776 comprising of 102 features. Hence the average number of suggestions given by each student was 10 suggestions implying a high interest by the participants in the quality of design of their learning space to reflect on their overall satisfaction during e-learning sessions. Moreover, by investigating the effect of specific design elements of an educational building, this research can help initiate the development of a framework or recommendations for building codes, for educational facilities within 3D Virtual Environments, to complement existing codes for erecting such facilities in the physical real-life world. The results of this study disseminate findings from a series of pilot studies in the use of 3D VLEs to specifically support practical user-centered teaching and learning in a virtual campus hence fostering student skills. Furthermore these are recommendations for possible applications of the technology through the use of a variety of educational scenarios in 3D Virtual Learning Environments. The key contribution is to be useful to others as examples of executable approaches and designs to improve teaching and learning content in a 3D virtual world. Additionally, initiated discussions, triggered debates and offered brainstorming opportunities for students during sessions, with respect to the use of such assistive technologies in Higher Education, were highly interactive and required the students to engage in a series of activities, including hands-on experience.

REFERENCES


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Noha currently teaches under-graduate and post-graduate students delivering education and guidance in a variety of topics including programming, business information technology (BIT), architecture and graphics design. Her BSc., MSc. and PhD degrees in Engineering encompass all of the previously mentioned disciplines. She is also a practicing architect and graphic designer both in the physical and 3D virtual worlds. Noha has publications connected to education and design of 3D Virtual Environments in numerous peer reviewed international conferences, journals, workshops and book chapters.

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