Whose turn to renovate the class today?
Analogy between Impact of Architectural Design Characteristics of Learning Spaces on Learners in the Physical World and 3D Virtual World

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Abstract. This research starts by establishing from literature the importance of architectural design elements of physical learning spaces on face-to-face learning, hence, after illustrating examples of different types of architecture in Second Life, delves into exploring the effect of individual architectural features of 3D virtual building design, such as color, shape of class, lighting and open spaces, height of space, textures and other aspects on higher education learners during online e-learning sessions conducted in virtual worlds, in an analogy with the physical world. Learners are divided into three groups: (i) under-graduate students, (ii) post-graduate students, and (iii) adult learners and researchers. Results comprising charts and diagrams capturing, using surveys, the extent of learners' satisfaction from being inside different 3D virtual university campuses in Second Life, representing different variations of architectural design elements in each learning space, hence their contentment from specific design characteristics, preferences and suggestions for design of a better learning environment are demonstrated. Moreover, this presentation will reveal how this research can help initiate the development of a framework or recommendations for building codes, for educational facilities within 3D Virtual Environments, to complement or contradict existing codes for erecting such facilities in the physical real-life world.

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

1   Introduction

"*All architecture is shelter, all great architecture is the design of space that contains, cuddles, exalts, or stimulates the persons in that space.*"
The above quotation by Philip Johnson has been shared enthusiastically by many researchers who have always believed in and thus toiled in investigating the effect of the architectural design elements of educational buildings in the physical world on students' learning experiences. Such effects are evident regardless of the learning context or level of study, and we frequently find new cases published from a variety of fields taught at Schools or University level that have unsurprisingly proven that 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 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 [1]. Furthermore, fixed windows and closed ventilation systems do not allow teachers to control the physical environment. Operable ones allow bringing in smells and sounds of surroundings [2]. The Ohio University Facilities Commission also noted that students participated twice as much in discussions in classrooms with "soft", 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 with man-made lighting) 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 [3]. 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 [4]. Kaplan as quoted by Evans [5] had suggested two criteria, which make an environment preferable by individuals in the physical world:

- Structural features that provide coherence including continuous texture gradients, thematic color or graphic patterns and variable but identifiable physical forms.
- Moderate spaciousness and occasional structural irregularities.

The effect of all the above features on student e-learning remains to be investigated in 3D virtual worlds. Some of the previously mentioned factors are non-existent in virtual worlds, for unlike auditory, visual and kinesthetic or tactile related factors, touch, thermal or olfactory factors cannot be perceived [6] e.g. ventilation and acoustics, hence have no effect on student learning inside virtual worlds. However despite this fact, would it still be logical to assume that other architectural aspects of 3D virtual learning spaces e.g. dimensions, finishing etc. would also have an impact on students' e-learning enhancement analogous to that of physical architectural elements of learning spaces on physical learning? This is the primary objective to be answered within this extended research.

The novelty in e-learning practices afforded by 3D Virtual Learning Environments (3D VLEs), such as Second Life, has persuaded many universities, such as Harvard, Princeton, Oxford, and over 400 more, in Second Life alone for example, to erect 3D virtual campuses for conveying e-learning to various varieties of students [7]. Such prospects include experimentation, teleporting between sites [7], flying, game-based activities, role-play [8], modeling and co-creation, immersion, critical incident involvement, medical training [9] and many other practices.

Along with this movement arose many inspired opportunities for creating buildings that cross the limits of reality and probe into the realms of imagination of the designer. This is because of the essential difference 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 friction or gravity [10] which can be resisted to have 3D virtual buildings floating in midair or engrossed under the deepest ocean. Such novel construction techniques have also been used to erect virtual university campuses in 3D VLES to produce a wide diversity of designs that range between realistic portrayals or replicas of physically existing campuses, and completely imaginative embodiments [11]. It is no wonder then that 3D Virtual Worlds' users from all genres, including students, are fascinated with the desire to build, design, redesign and renovate their virtual learning spaces constantly to their own satisfaction and enjoyment.

2   Design Practices in Virtual Worlds

There are presently no documented investigations representing the effect of 3D architectural design elements on the e-learning process of students, nor are there 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 [12] suggested using architectural and environmental elements such as landmarks, signs, paths (easily identifiable starting point, course, intersections and destination), thresholds (e.g. doorways expressing relationship of the space with the surroundings) and boundaries (fences, walls etc.) to aid students' way finding, or using large scale spaces (but with no detailed specifications provided) [13], or Feng-Shui flow of navigation style of design [14]. Bridges & Charitos 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) [10]. Minocha & Reeves [15] 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 experienced by the learners, only pedagogical factors were identified not architectural factors [16]. A research on user orientation within 3D VLEs was conducted by Charitos [17] showing that the application of any rotation on the 3D build in relation to the path clearly decreases the easiness with which a person orientates in this place, although this is unlikely to occur during an e-learning session. Furthermore, based on other conducted experiments, Bridges & Charitos [18] affirmed that in general design of virtual environments, avatar movement in a virtual environment is significantly enhanced by the use of dynamic textures and rhythmically repeated elements in paths. Charitos also confirmed that ratio of dimensions of a space can induce avatar movement towards the centre or the boundary of that place (if square) or along its main axis (if horizontal or vertical) - hence a virtual space which has the volumetric proportions of a 'run' (i.e. one dimension is more than 2 or 3 times the other dimensions) induces movement towards the direction it implies [19]. However:

- There is no indication how this feature (or any of the above attributes mentioned in general) affects the e-learning experience or 3D educational spaces.
- Even more, while Norberg-Schulz [20] describes a place as "a totality made up of concrete things having material substance, shape, texture and color", and Bridges & Charitos [10] state that the overall impact of an object in a virtual world is determined by its geometry, color, texture etc., there is no recorded research of impact of specific architectural elements e.g. color, texture, shape, dimensions, seating arrangements, lighting etc. on students or users in general;
- nor students' specific preferences and proposals for these different architectural design features of virtual learning spaces, especially towards the newly emergent types of architecture in virtual worlds that are not available in the physical world as will be illustrated later.
- In addition while Bridges & Charitos [10] 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 [16], 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 [16], not knowing whether or not these same design conventions are suitable in virtual worlds for the e-learning experience of a student, moreover actually proving inadequate or unnecessary in many cases [12].

3   Hypothesis

Bourdakis and Charitos [21] previously affirmed that the nature of space in virtual environments (VEs) is fundamentally different from the nature of real space and consequently the architecture of VEs requires new theory and practice. Additionally, since the nature of space in the real world is fundamentally different from space in VEs, designers of virtual spaces should be provided with background knowledge from disciplines relating to issues of virtual reality technology rather than knowledge of technical issues relating to construction in the real world. On a separate note Downs and Stea [22] stated that "human spatial behavior is dependent on the individual's cognitive map of the spatial environment" (the process of acquisition, incorporation and storage of information, available in the environment is called cognitive mapping). It is thus logical to inquire the presence of an impact of the surrounding 3D learning environment on students' behavior and learning in 3D VLEs.

In agreement with the above declaration, this study is part of an ongoing research focusing on verifying the hypothesis of presence of an impact for architectural design elements of 3D virtual learning spaces on students' e-learning within them, whether similar or different to that existing in the physical world. Furthermore this research aims at defining that impact, deriving best architectural design characteristics of a 3D educational facility to enhance the e-learning experience within it, and hence closing the gaps in research mentioned in the previous section. The current paper distinctively raises the query on and captures the extent of students' satisfaction and contentment from specific internal architectural design elements of virtual educational buildings within 3D VLEs. This will help produce analytical statistics as a preliminary indication of the effect of these architectural characteristics on students' e-learning in 3D VLEs. Learners' ability to navigate by flying within a virtual space unlike the physical world, and constant change of camera view regardless of position of avatar, changes the user's viewpoint, scale and experience within the domain [19]. Hence results and impact of architecture anticipated from this research are expected to vary from those in the physical world. Consequently this general study of students' perceptions of their virtual learning spaces gives the opportunity to issue recommendations for future enhancement of 3D virtual learning spaces and future creation of a framework for designing educational facilities and learning spaces in 3D VLEs analogous to its counterpart in the physical world.

4   Types of Architecture Physical and Virtual

Charitos defines existential space as a system of three dimensional relations between meaningful objects [6]. Hence arises the need to identify first the different architectural spaces or types in virtual worlds, before studying the effects of the 3D relations between their objects on the users of the space, namely the learners in this context.

In the case of a simulation of a real-world place, all spatial entities and objects of the environment are modeled precisely so as to imitate their physical existence. However when we need to design a virtual environment which comprises several spatial entities, which do not necessarily have real-world counterparts and which will accommodate the interaction of the operator with the VE, the design of the VE may benefit by making use of architectural design knowledge. [6]

Minocha and Reeves [15] categorize 3D building styles as follows: Photo-realistic (identical replica of equivalent in reality), artistically-realistic (similar to equivalent in reality), functionally-realistic (has no equivalent in reality but is realistically designed), metaphorically-realistic (implies realistic functions), hybrid (mixture of realistic and

imaginative design), fantasy (imaginative design defying reality), abstract (ambiguous design).

The authors of this research provide a comparable categorization as follows:

- **Static, Realistic** – emulating real life architecture

For example we find the recreation of Shakespeare's Globe Theatre by designer Ina Centaur. Also DESIGNING DIGITALLY is a leading firm in designing buildings in second life. Some of its creations include:

Eastern Iowa Community College (2007) is a building sculpted in the shape of the school's logo which resembles an "E" [23].

As can be seen very little architectural approach is based towards identifying learning needs of students from architecture. Design is based mainly on requirements of shape, appearance, size etc. dictated by the owners of the university buildings – which implies a more ad-hoc approach to architectural design not according to certain scientific specifications. One Designer's ad-hoc recommendation for architectural design of 3D virtual environments included: using large scale & large height buildings (since the default viewpoint is behind and above your head, not inside the head, and the movements are clumsier than in real life), and you can leverage the ability to fly, to move your camera around, etc. However it has been noticed that exact depictions with exact same dimensions are not always as successful as their physical counterparts e.g. same height spaces and multiple internal corridors and storeys at Ohio University campus virtual campus [24].

Fig.1 Examples of static realistic 3D virtual architecture

- **Static , Imaginative** - Gravity Defiant Approach

A major problem with current SL architecture is not reaching the possibilities of the 3D VLEs realm of design. Mimicry of real-world forms is ever-present in this digital landscape, created without the knowledge of why it looks the way it does. For example, homes with a steeply pitched roof, when there are no snow-loads or moisture problems. 3D VLEs offer tools to build just about anything imaginable – there are no confinements by laws of gravity and characteristics of building materials. E.g. Second Life School of Architecture (SLSA) is made up of 1062 floors with no vertical connections. It has only implied structure and implied spaces without doors, windows, or roofs. Also Scope

Cleaver's Diversity Building for Princeton University, and The Office of Designer Dingson demonstrated below [25].

However despite the above approach to go beyond the realms of imagination in designing architecture of buildings, the effect of this on students learning has yet to be discovered.

Fig.2 Examples of static imaginative 3D virtual architecture

- **Dynamic, Realistic &   Dynamic, Imaginative** - REFLEXIVE ARCHITECTURE

One kind of new virtual architecture is reflexive architecture. In physical reality, architecture is a static and relatively motionless artifact. Dr. David Fisher's Dynamic Tower however is the first building in motion that will change its shape and add a fourth dimension to architecture: Time. The shape is determined by each floor's direction of rotation, speed, acceleration and the timing; with timing meaning how each floor rotates compared to the other. The rotation speed will be between 60 minutes and 24 hours for one revolution. Residents can control the speed and direction of the rotation by voice command. The other floors are commanded by the architect, by the mayor or whoever will have the password to the computer program that will give the building a different shape at every glance. "Designed by Life, Shaped by Time" is the concept of the Dynamic Tower according to Dr. Fisher's vision of the future of architecture [26].

In a virtual environment, the architecture is capable of transcending the limitations of static buildings, and become far more dynamic; behaving more like a liquid than a static and passive artefact. In reflexive architecture, the form of the architectural prims, their shapes, sizes, locations, colours, textures etc. change with the contact or touch of the user / avatar; so the space dimensions become dynamic as you move through it – creating or

Whose turn to renovate the class today?
Analogy between Impact of Architectural Design Characteristics of Learning Spaces on Learners in
the Physical World and 3D Virtual World 7

removing new walls, changing their directions etc. An example is Keystone Bouchard's Gallery of Reflexive Architecture demonstrated the previous page [27].
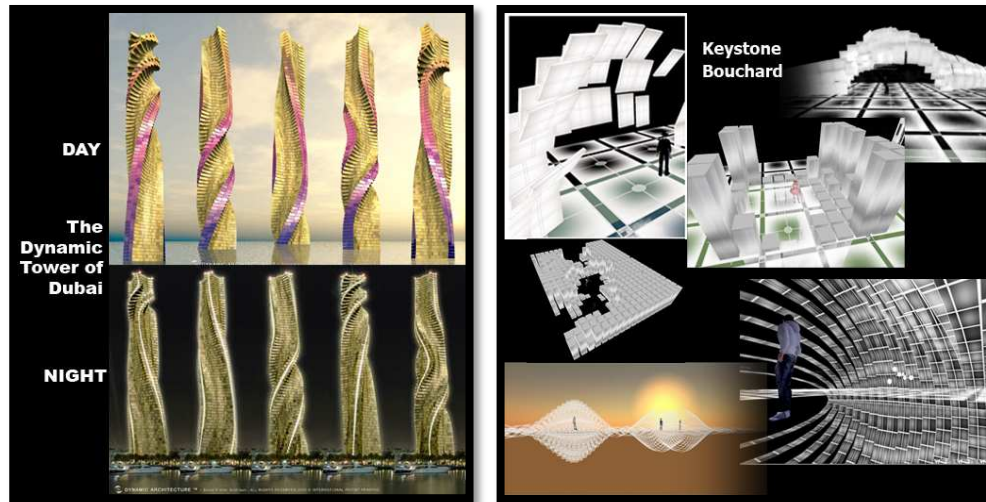

Fig.3 Examples of dynamic architecture in real-life (the Dynamic Tower) and dynamic reflexive architecture in the virtual world

5 Method

The architectural design elements of a 3D virtual learning space which were taken into consideration for study within this research were nominated based on:
- previous researchers' interpretations of what are components of a space, and also
- researched architectural elements in the physical world and their impact on learning.

Regarding the former point, according to Ching [28] the qualities of the place depend on the properties of the enclosure e.g. proportion, scale, form, color, texture dimensions, shape, surfaces, edges, openings. These define the place and affect the way that we experience it. Charitos [6] adds that space establishing elements are either bounding objects and edges e.g. walls, ceilings etc. suggesting a special form, or bounded objects which function more like landmarks that "*cannot be entered into*". Bounded objects are outside the scope of this research for indirect impact on the e-learning process taking place *within* a virtual learning space. Fraser [29] further suggests that the impact of the object in a virtual environment is determined by its geometry, color among other attributes. As regards to the usage of door openings which Charitos [6] recommends utilizing only when walls are not penetratable, it remains to be investigated which condition would be more effective for students in a virtual learning space..

Regarding testing for the degree of open surfaces in a learning space, Thiel [30] previously classified spaces by their degree of spatial definition: Vagues - spaces of an indefinite and ambiguous form, Spaces - intermediate degree of explicitness, Volumes - explicit, completely defined spaces resulting from the use of complete and adjoining surfaces in all positions. Charitos [13] hence argued that when the relations between the 'inside' and 'outside' of a place are clearly defined by the boundaries of the place, a person can identify with the place, and feel secure in there. This leads to a hypothesis that in a VE, as is the case in real environments, the degree of explicitness with which this place is defined by its boundaries determines the feeling of comfort with which we engage into an

activity in this place and consequently affects the performance of a particular activity in there. However, experimental results did not fully support this hypothesis. The evidence showed that very clearly defined boundaries may prove problematic and their affective impact may be negative. In the case of vaguely defined spaces, results showed that, despite the lack of a sense of enclosure, most subjects adapted to the openness of space, felt positive about navigating and performing a task without being constrained by boundaries, but could at times experience feelings of insecurity and distraction, perhaps due to the non-realistic character of the designed spaces [19].

Regarding testing for the form and dimensions of a learning space, Norberg-Schulz [31] stated that "centralisation symbolises the need for belonging to a place, whilst the longitudinal movement expresses certain openness to the world". This might indicate that spaces with cubical dimensions (or similar width and length) invoke a sense of stability in students and settlement in the space thus positively affecting the e-learning process, unlike longitudinal spaces which might induce sense of restlessness in students and desire to move which might hinder the e-learning process. In the same vein, Charitos et al. [32] noted that users are more used to being in 3D places where walls are rarely much bigger than floors or ceilings, which is another factor worth investigating in 3D virtual educational spaces.

Regarding testing for colors of the educational space boundaries (namely walls, ceilings, floors), Charitos et al. [32] reported that colors of 3D surfaces affected the way that users within their experiments orientated within the place. It seems that the difference in color between floor/ceiling and walls of the place influenced the identification of these surfaces within each place. However, when color of both bigger surfaces - floor and ceiling - was the same, subjects had to detect other cues in order to differentiate between the two.

To verify the above described uncertainties, it was imperative to investigate and analyze students' evaluative reactions towards the presence of certain variations of specific design elements within elected 3D virtual university campuses. This was accomplished by first selecting 16 virtual university campuses, within Second Life (as a representative of 3D VLEs), that embody 16 variations (described later) for 8 major internal architectural design elements used for building in the virtual world.
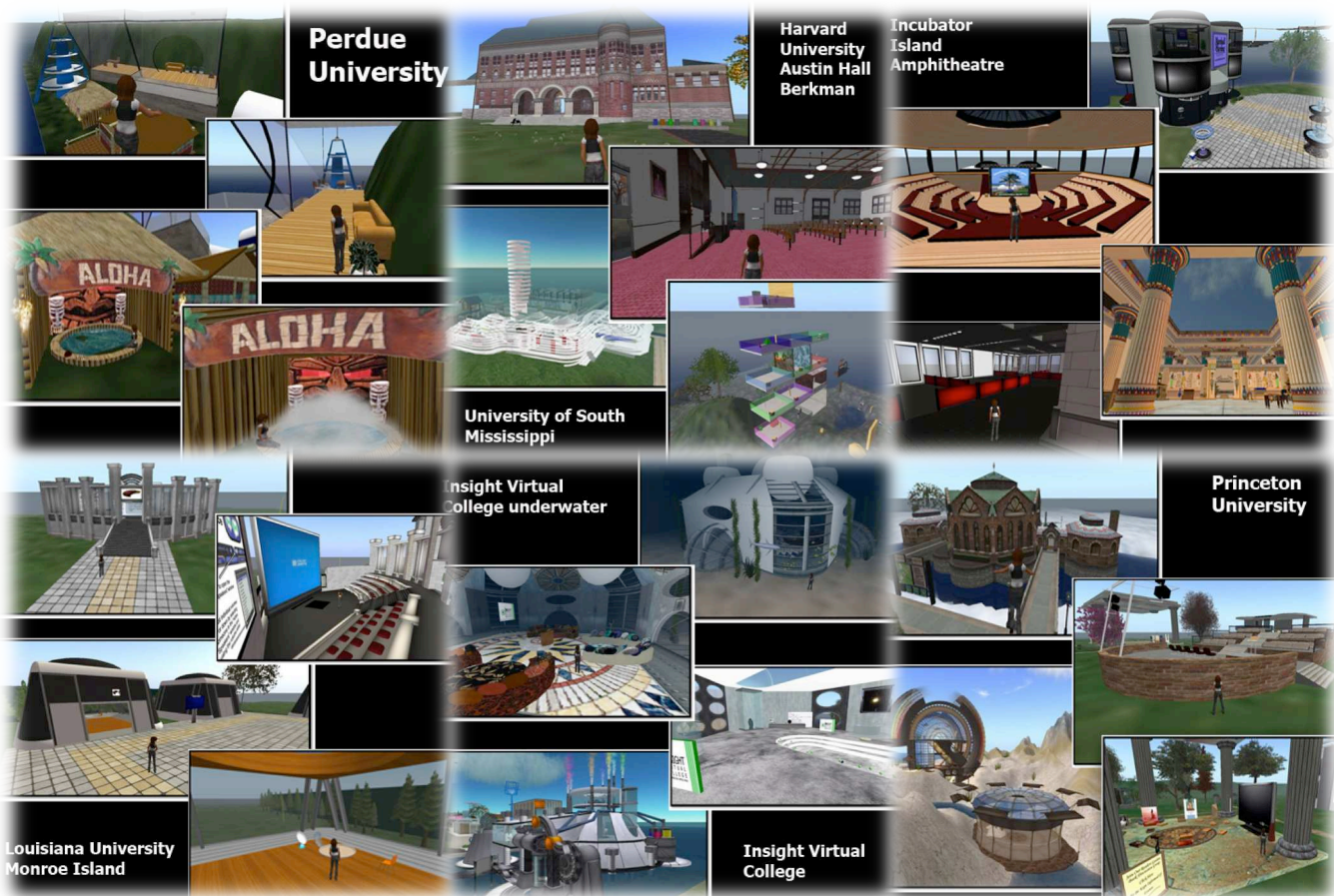
Whose turn to renovate the class today?
Analogy between Impact of Architectural Design Characteristics of Learning Spaces on Learners in
the Physical World and 3D Virtual World   9

Fig.4 Images of the 16 Virtual University campuses in Second Life used in this study

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

Despite the presence of other architectural design elements, only the above commonly used ones were selected since the purpose of the research was not to identify the effect of an exclusive list of elements on students, but rather to deduce whether internal architectural design elements in particular affect students' satisfaction from their 3D virtual learning space, hence indicating a possible effect on their learning experience during an e-learning session. A mixed quantitative/qualitative research approach was subsequently adopted, comprising of survey questionnaires containing closed and open ended questions [11], focus groups and interviews; however the description and results of the students' survey open and closed-ended questions are the main interest and focus of this current paper (the other data being discussed by the authors in other submissions).The partaking sample of users consisted of 84 participants from the School of Engineering in Middlesex University, UK. These were divided into the following categories which correspond to the different clusters of users utilising 3D virtual university campuses for e-learning sessions: 31 undergraduate students, 33 graduate students, and 20 members of faculty representing adult learners from different age groups (30 to 60 years old). The purpose of the study was explained to them, and only those volunteering to participate remained in the survey session, and were taken on a virtual tour inside Second Life, where they were shown each of the 16 nominated sites in sequence. After adequately interacting with each individual site and its spaces, participants answered a set of 9 likert-scale questions that denote their opinion on how well they like each of the 8 previously mentioned design elements of that site, using a 7-level Likert-scale (strongly agree, agree, partially agree, neutral, partially disagree, disagree, strongly disagree) [12]. The questions were:
1. This learning space has an attractive building style (e.g. modern, classic, baroque)
2. This learning space has attractive surroundings (e.g. greenery, lighting, water)
3. This learning space provides a suitable seating arrangement (e.g. circular, rows)
4. This learning space provides a pleasant wall aesthetic/design (e.g. 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 and size for an educational environment (width to length to height area ratio)
9. This learning space offers a learning environment that you like to have classes in.

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

Subsequently, open ended questions asked students to write what design elements they liked and disliked most in each of the 16 educational sites they visited, what design elements they would prefer to be available within their own 3D virtual learning space.

Quantitative results were calculated from the numbers of students voting for the different Likert scale answers, where positive numbers indicate student satisfaction, whilst negative

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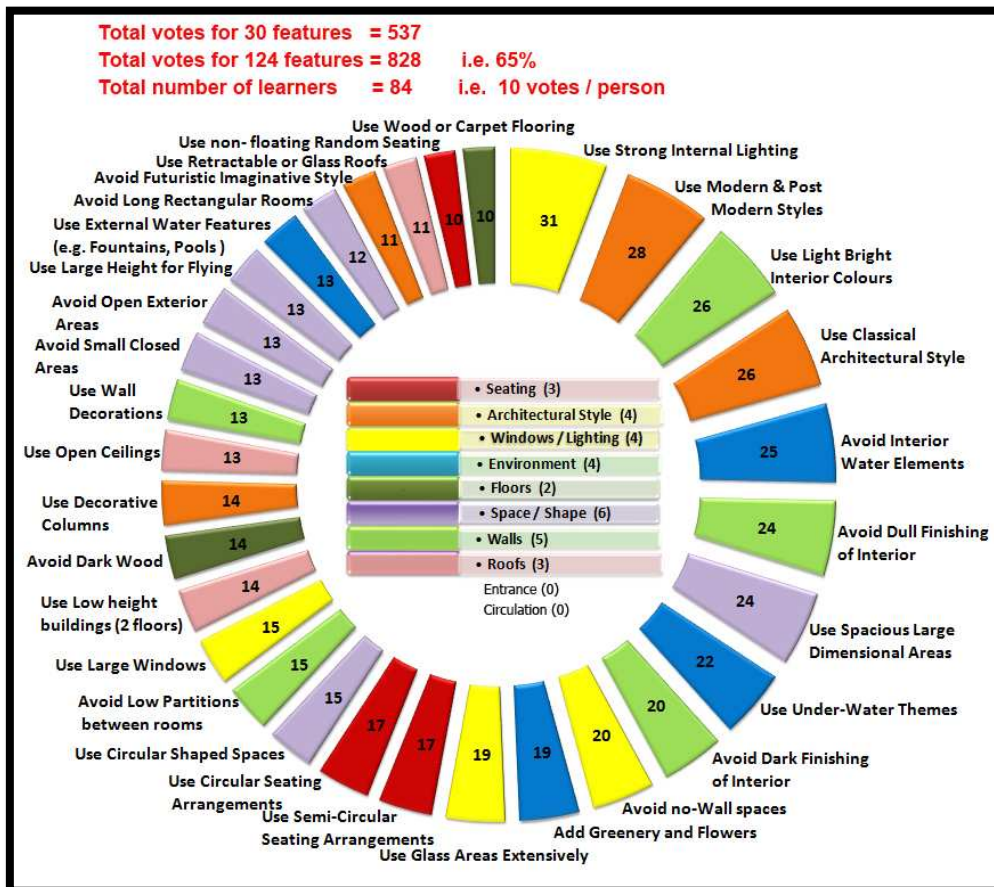
6. Result

Fig. 5 Highest 30 recommended architectural features of a learning space proposed by learners

The above chart illustrates the top 30 architectural design characteristics proposed or requested by students from all age groups to be present in their ideal 3D virtual learning environment (representing 65% of total votes). As can be seen, these propositions are divided into 8 major categories, the highest achieving were those related to windows & lighting, walls, internal architectural style and environmental elements; whilst shape of space, floors, roofs, seating arrangements were less in demand, and those related to building entrance and circulation between the learning spaces were non-existent within the highest 30 characteristics (although existing later on in the list). This can be attributed to the fact that the elements of space most seen directly at student's eye level are the lighting, walls, design style and surrounding environment (e.g. water elements, greenery etc.), and

thus have 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. As for building entrance and circulation, since these are outside the immediate learning space that the students take their e-learning session in, they are probably not remembered as essential categories for design by students.

On an individual element's basis, the following could be noticed. The highest recommended characteristic was strong internal lighting, bright and light non-dull or dark colors, spaciousness and extensive use of glass areas (which attributes to high intensity of lighting). As for building style, simple modern and plain classic styles were most preferred with no over decoration or imagination so as not to cause distraction for learners. Semi-circular or circular seating arrangements (along with circular shaped spaces) also seemed most agreeable for students. An unexpected finding was the fact that students recommended abundance of greenery, flowers and water elements (e.g. fountains, sea etc.) but surrounding their learning space not on the inside of it, again so as not to cause distraction among them but rather comfort surrounding them.

In general, the fact that 828 total votes comprising 124 different features were recommended by students i.e. almost 10 suggestions per student is definitive proof that architectural design of the virtual learning space is important in students' opinions.
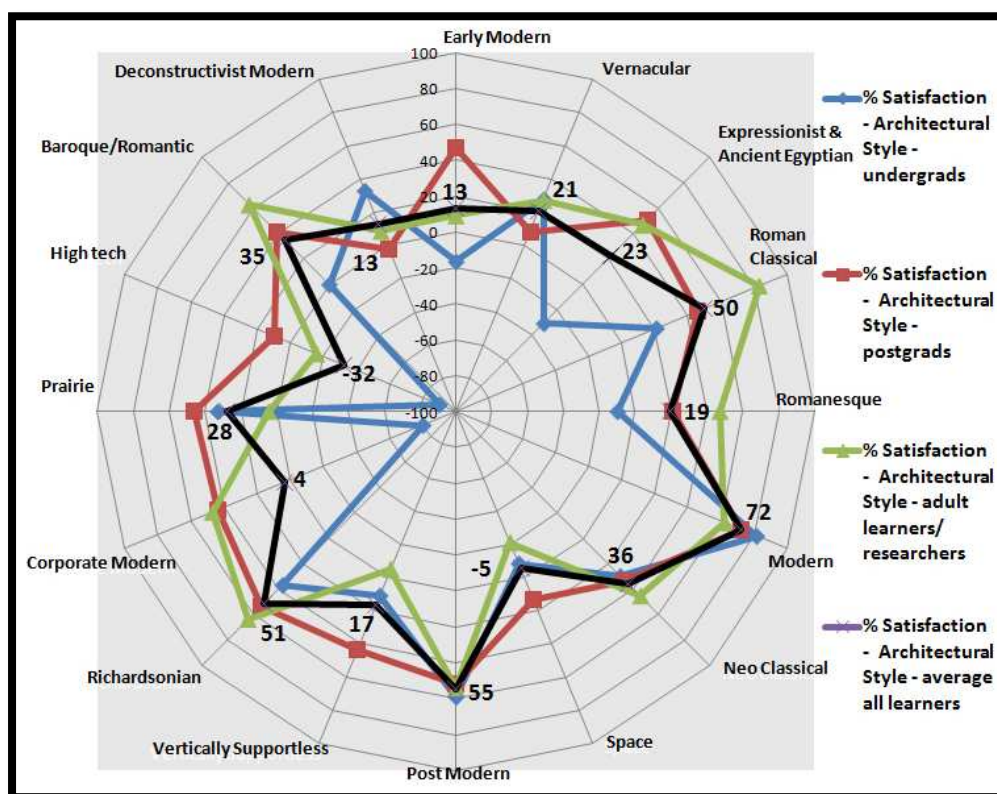

Fig. 5 Percentage satisfaction of learners from the Architectural style of the Educational Facility

The chart above shows that students' highest preference from all age groups is towards modern (and post-modern) style which coincides with findings from the previous propositions. There seems to be difference in opinions regarding other styles with significant tendency of adult learners towards classical styles. However all groups seem to dislike space themed, high tech, supportless and deconstructivist styles which are all too futuristic and imaginary compared to physical world designs. This indicates that for an e-learning environment, learners probably prefer simple, stable realistic architectural designs for their learning space that   offer no distraction and are similar to real life educational environments.
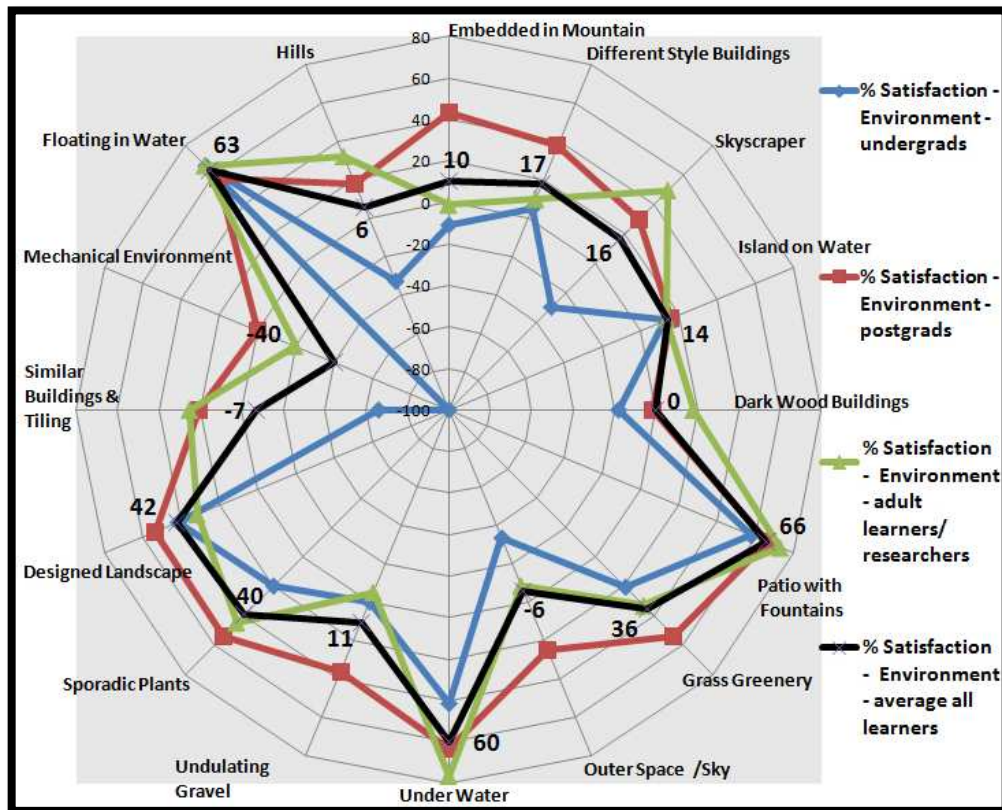

Fig. 6 Percentage satisfaction of learners from the environmental features of the educational facility

The former chart above reveals that all student age groups have a fondness towards water themed elements whether patios with fountains, surrounding sea or being underwater, along with preference for presence of greenery, flowers etc. However they all seem to oppose being in dark wood spaces. Surprisingly while the younger age is expected to embrace innovation, the undergraduate students especially disliked learning environments with space or mechanical themes or even being in very high skyscrapers with similar monotonous design during e-learning.
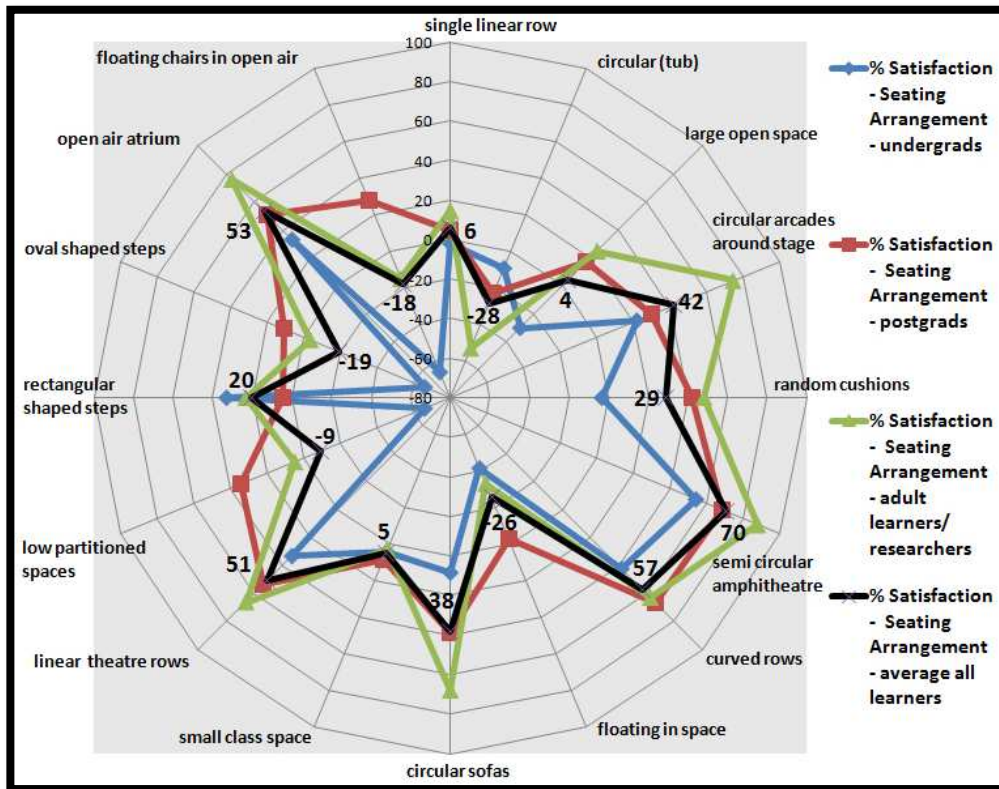
Fig. 7 Percentage satisfaction of learners from the seating arrangements of the Educational Facility

The preceding chart shows a definite preference to all forms of circular, semicircular and curved forms of seating arrangements, especially by adult learners. Having an open air atrium is also very much preferred by all ages of students. On the other hand they all particularly disliked floating in space. Undergraduates showed strong dislike to oval shaped steps and low partitioned spaces.

As for students' satisfaction and contentment from wall and floor designs depicted in the following 2 charts, tastes and personal preferences varied greatly between groups of different ages. Some of the common factors were preference of light and colored finishing whether stucco or wood or brick or marble (with varying degrees), and complete dislike for concrete and metal finishing.

As for window style fondness shown in the subsequent figure 10, while arched, vaulted, domed and bowed windows, which all have curvature lining, appealed to the students, completely circular windows were not preferable. Also while spaciousness and usage of large areas of windows was shown favorable earlier, it seems that complete open space or no walls is undesirable like using no windows at all in closed walls.

This concept is further emphasized in figure 11 below which shows that the most preferable percentage of open spaces is around 50% of the total wall and ceiling surface area of the space. More or less than that becomes undesirable by students.
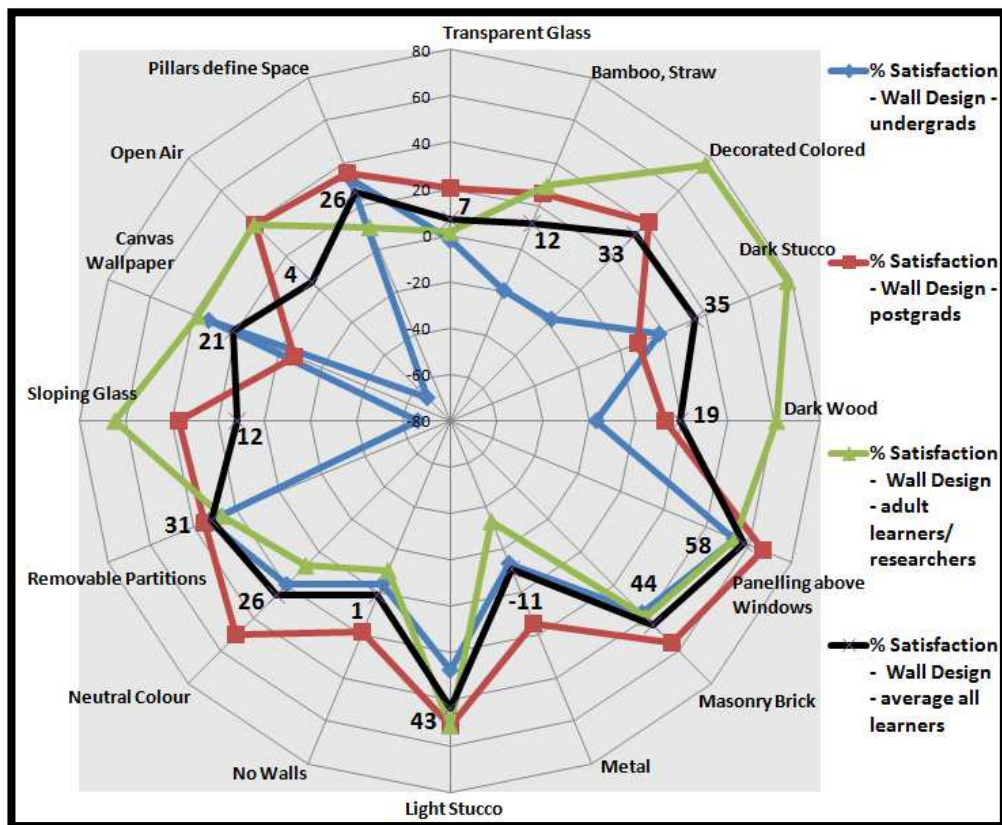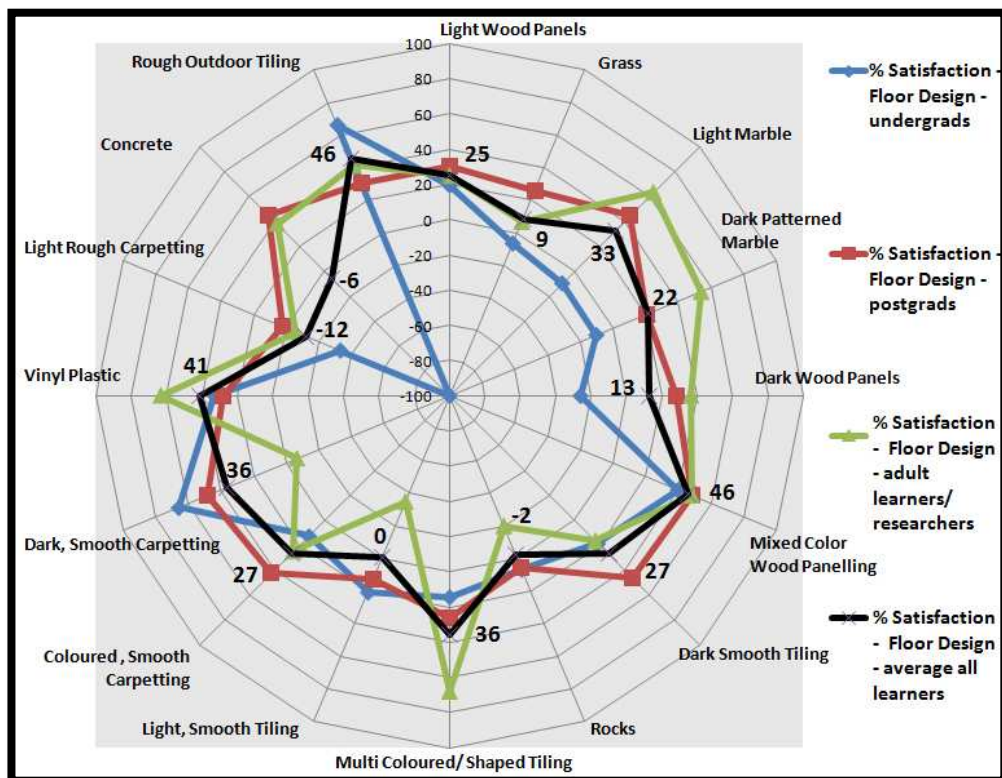
Fig. 8 Percentage satisfaction of learners from the wall design of the educational space

Fig. 9 Percentage satisfaction of learners from the floor design of the educational space

Whose turn to renovate the class today?
Analogy between Impact of Architectural Design Characteristics of Learning Spaces on Learners in
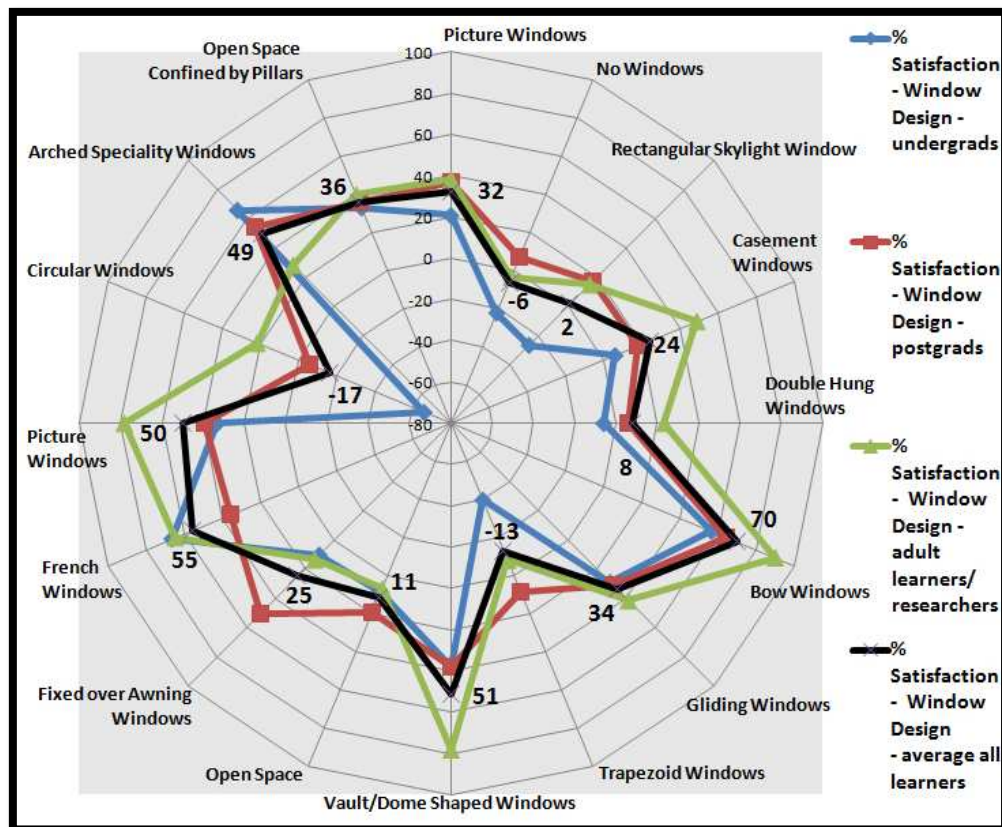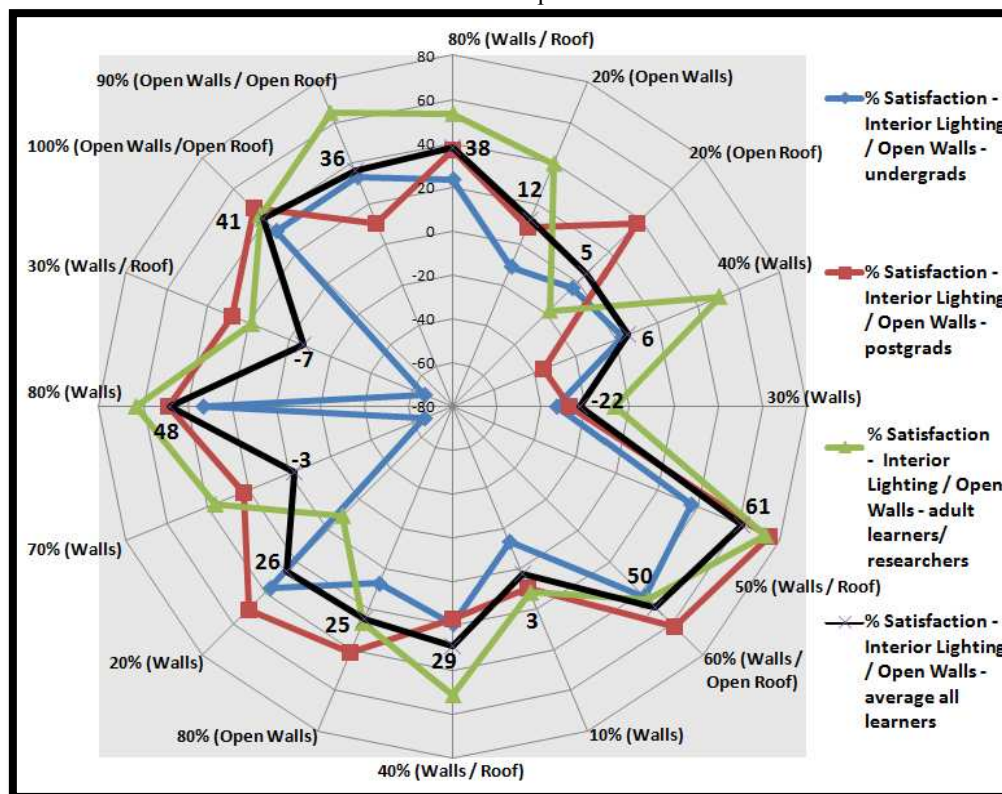the Physical World and 3D Virtual World   15

Fig. 10 Percentage satisfaction of learners from window design of the educational space

Fig. 11 Percentage satisfaction of learners from interior lighting / open walls of the educational space
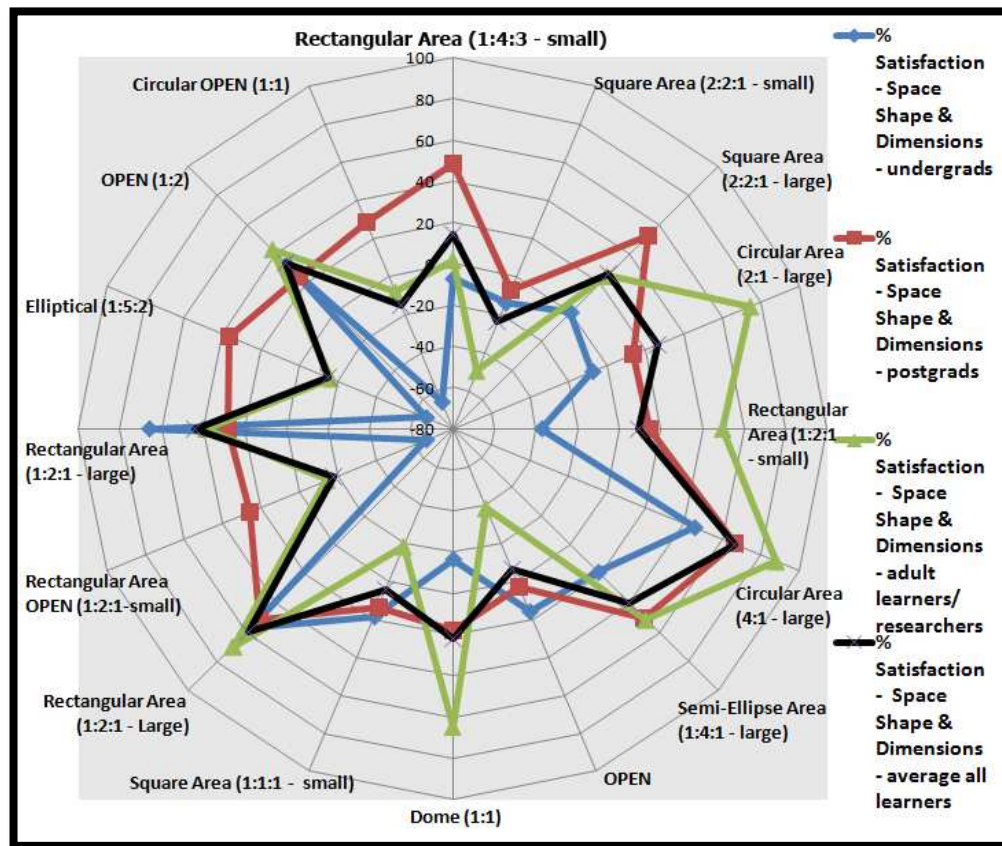
Fig. 12 Percentage satisfaction of learners from the space, shape and dimensions of the educational space

Last but not least, the preceding chart validates previous findings: for the most preferred space shape was found to be circular, to contain circular and semi-circular seating arrangements (as shown earlier). Also again here, open spaces were demonstrated to be undesirable as established in the previous section. Large rectangular areas appear to be of more popularity than square areas especially with a ratio of 1:2 length to width. However undergraduates showed particular discontent towards rectangular areas especially if very narrow or small.

6   Conclusion

Contributions offered by this research provide confirmative evidence for the original hypothesis posed within this study that architectural design elements of 3D educational facilities in 3D VLES have an impact on students. This impact is exemplified through the definite differences in preferences and contentment of students towards diverse variations of each architectural element tested in this study e.g. style, shape, finishing etc. It is also evident through the abundance of suggested propositions for enhancement of 3D learning spaces provided by students.

Percentage preferences obtained towards a feature were sometimes almost unanimous by all student age groups and sometimes were variable. The commonly agreed or disagreed

Whose turn to renovate the class today?
Analogy between Impact of Architectural Design Characteristics of Learning Spaces on Learners in
the Physical World and 3D Virtual World   17

on architectural features can form a basis, with further investigation, for a framework of guidelines on how to design 3D virtual educational facilities to enhance the e-learning experience within them, analogous to the design specification codes available in the physical world for designing such facilities.

7   References

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