Assistive Technologies and Environmental Design Concepts for Blended Learning and Teaching for Disabilities within 3D Virtual Worlds and Learning Environments

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ABSTRACT

3D Virtual Learning Environments (3D VLEs) are increasingly becoming prominent supporters of blended learning for all kinds of students including adult learners with or without disabilities. Due to the evidenced effect of architectural design of physical learning spaces on students' learning and current lack of design codes for creating 3D virtual buildings, this case study aims at evaluating the suitability of the architectural design elements of existing educational facilities and learning spaces within 3D VLEs specifically for delivering blended e-learning for adult students with disabilities. This comprises capturing student contentment and satisfaction levels from different design elements of the 3D virtual spaces in an attempt to issue recommendations for the development of 3D educational facilities and hence initiate a framework for architectural design of 3D virtual spaces to augment accessibility, appeal and engagement for enhancing the e-learning experience of under-graduate, post-graduate and independent-study adult learners with disabilities within these virtual worlds.

INTRODUCTION

This study ultimately endeavors into providing recommendations and hence an initial architectural design framework for creation and deployment of 3D virtual learning spaces within 3D virtual worlds, used for students' blended learning experiences comprising of online courses supplementing face-to-face instruction. Since blended learning advocates mixing different learning environments to deliver education, e.g. combining face-to-face instruction with computer mediated instruction, 3D VLEs have been abundantly used as a technological medium for education, supporting traditional learning. For example, students can be immersed in a 3D VLE, performing learning activities while synchronously being inside a physical classroom; or whilst being in different physical locations; or even asynchronously at different times. The significance of this research hence arises from the increased focus on students' technological involvement which has become one of the motives significantly adjusting learning space

design in the physical world (Whitmer, 2009), and thus analogously expected to have an impact on learning space design in 3D virtual worlds. Our aim through this research is therefore to define architectural design elements of 3D virtual learning spaces that can encourage adult students' satisfaction (specifically learners with disabilities) from these learning spaces and thus enhance students' e-learning experiences in 3DVLES. This would hence automatically reflect on improving the students' overall blended learning experience comprising of both the physical and the virtual.

The utilization of 3D VLEs has proven especially beneficial for students with disabilities who might have different forms of physical challenges hindering their participation in "real-life", face-to-face education. Learners suffering from various types of disability constitute about 8% of all the people who use the worldwide web technology. Their disabilities range from visual, hearing and movement impairments to cognitive, language impairments and seizure disorders (Gnome, 2008). Virtual World systems in general are currently being utilized profusely for rehabilitation purposes as they induce encouragement to overcome disability by providing students with a sense of accomplishment for tasks they might not be able to achieve in "real-life" (RL). This is because they can create customized avatars, within 3D virtual worlds, which do not have to be disabled, and thus fly and move in 1st and 3rd person views freely (Flynn et al., 2008). Hence a person's disability in the physical world could be different from that in the virtual world e.g. a person who cannot walk in "real-life" would be able to function normally online as his impairment would not hamper keyboard and mouse control inside 3D VLEs, whilst a person with sensory-motor problems might be able to move normally in RL but have problems in manipulation online due to lack of manual dexterity. Assistive Technologies (AT) and Universal Design for Learning (UDL) are two approaches currently being used to achieve this purpose of improving education for students with disabilities, where UDL focuses on enhancing the physical learning environment as a whole and AT centers on assisting students individually (Edyburn, 2005). Within this research the authors adopt the AT approach where design of 3D virtual Learning environments can be specifically customized to accommodate specific needs of disabled users, particularly according to gender, the individual type of disability, and the age group of the user, as will be elaborated in consequent sections.

Furthermore, there is ample literature in the physical world depicting i) the effect of architectural design elements of "real-life" educational spaces on students, ii) presence of design guidelines for physical educational facilities, and iii) special design characteristics needed to accommodate students with disabilities. These were imperative to generate architectural guidelines and specifications for designing physical educational spaces to provide adequate accessibility to cater for disabled student's needs, for whom the physical environment plays an increasingly fundamental role in attaining progressive learning outcomes (Whitmer, 2009). However there are no corresponding attempts or design codes available to enhance the accessibility of e-learning spaces in 3D VLEs, which are the virtual equivalent of physical learning spaces. Instead, 3D virtual builds are currently being created arbitrarily according to each designer's desires or physical world experience in building regulations (Saleeb & Dafoulas, 2010a). Hence this suggests that disabled students' architectural space design requirements for usability and accessibility in virtual worlds could be different from those in the physical world, which is the area currently lacking in research.

This study is part of an extensive research aiming at evaluating and defining best architectural digital design practices for creating 3D virtual educational facilities, within 3D virtual worlds (VWs), for different genres of adult students, and specifically, within this study, for students with disabilities who are the focus here. As expressed earlier, the authors support within this case study the Assistive Technology (AT) approach of eliminating potential barriers to usability, and adjusting 3D virtual learning spaces to individual disability requirements according to gender, type of disability and student age group as elaborated subsequently.

BACKGROUND

Online 3D Virtual Learning Environments (3D VLEs) have been since their commencement a host for virtual campuses, created by hundreds of universities and educational institutions (Kay, 2009). The novelty in teaching techniques within these virtual existences offers e-learning opportunities for all diversities of students in many fields including science, medicine, engineering, business, law, computer science, humanities and many more. Such opportunities include experimentation, teleporting between sites, flying, game-based activities, role-play, modeling and co-creation, immersion, critical incident involvement, medical training and many other practices (Calongne, 2008).

Along with this trend emerged creative opportunities for erecting constructions that traverse the limits of reality and probe the extents of imagination of the designer. This is due to the fundamental discrepancy between the physical and the virtual world where there are no constraints on budgets, no engineering natural forces and material strength limitations, no infrastructure requirements, sound, ventilation regulations or even gravity which can be defied to have 3D virtual buildings floating in midair or submerged underwater (Bridges & Charitos, 1997). Such original building techniques have also been used to erect virtual university campuses in 3D VLES to generate a broad diversity of designs that vary between realistic representations or replicas of physically existing campuses, and completely fantastical constructions (Alarifi, 2008).

One of the factors that have been evidenced to affect learning in the physical world, the degree of assimilation of knowledge, achievement and enjoyment of students from education, is the architectural design and physical building characteristics of the space in which students learn (Eberhard, 2008). Such design features include color, texture, dimensions of space, lighting, and ventilation amongst others. On the other hand, scarce study has explored the effect of 3D architecture in virtual worlds on any genre of users, not just students in 3D VLEs, and their satisfaction and contentment from the architectural design (Saleeb & Dafoulas, 2010b). Furthermore, no academically performed research correlates between the blended learning techniques developing within 3D VLEs, and the architectural design specifications of the 3D virtual spaces, within which this e-learning is taking place, for students with disabilities; thus whether these design specifications have an impact on the effectiveness of e-learning on student users of 3D VLEs, including users with disabilities (Minocha & Mount, 2009).

The current research thus focuses, as one of its goals, on closing this gap by capturing the extent of disabled students' satisfaction and contentment from specific internal architectural design elements of existing virtual educational buildings within 3DVLEs; hence giving the opportunity to issue recommendations for future virtual learning space enhancement. As demonstrated later. this is done by studying the effect of individual architectural features of 3D virtual building design, such as color, shape of class, lighting and open spaces, dimensions of space, navigation components, textures and other aspects, on participants' blended learning during online sessions complementary to "real-lfe" sessions.

To support this notion, research describing design requirements in physical spaces for specific kinds of disabilities was investigated. Based on 3 case study analyses of three post-secondary institutions in the United States, three specific components of the physical environment were found to hold an increased value for a student with learning disability. These components were way-finding, formal learning spaces, and disability services spaces of the built environment (Whitmer, 2009). Complementary to this concept, the Americans with Disabilities Act of 1990 (ADA) prohibits discrimination on the basis of disability, so that people who design and construct buildings and facilities are responsible under the ADA to make them accessible to and usable by people with disabilities (Building Regulations, 2004). For example, regarding students with mobility impairments, one design specification states ramps should have a non-slip surface, 1.5m minimum unobstructed width and a maximum individual flight of 10m, with maximum gradients of 1:20 if longer than 5m, 1:15 if longer than 2m or 1:12 if shorter than 2m; also has top and bottom landings no less than 1.2m and intermediate Landings of 1.5m every 10m (American National Standard, 2004). There must also be a handrail on both sides, 900–1000mm high. As for elevators, they should be at least 1.1m x 1.4m and have a door with a clear opening of 800mm (Bright et al., 2004). For school buildings, stair rise should not exceed 17cm and preferred going 28cm. However, a building that offers only stairs for moving between floors or rooms is considered to create barriers for many, especially wheelchair users (Rose et al., 2005).

As for users with visual impairments, Levy (2009) for example reported that the amount of light within the learning space and how it shines should be controlled; glare and reflective surfaces should be avoided so as not to be difficult to see. Good color contrast is also crucial, e.g. for handrails and doors, to help users perceive the environment and find their way easily e.g. light-colored ceilings and walls reflect the light back into the room, while dark-colored ceilings and walls absorb the light. Light colored physical door frames (e.g. aluminium) or frameless glass doors can be extremely hazardous for people with sight problems, and revolving doors can be inefficient for people with movement disabilities (Levy, 2009). Surfaces and textures on both walls and floors, e.g. embossed wallpaper border or metal strips half way down the wall, can provide useful tactile information for people with blindness. This is in addition to using large print text, pictorial aids and sound cues but no background noise. However using tactile surfaces is not a viable issue in 3D virtual environments due to lack of touch sensation. Another sustaining study recommended walls be finished in pale matt tones but with contrasting darker skirting and doors to contrast or highlight position (Nottingham, 2008), while floor should have a clear color and tonal contrast with the walls (Bright et al., 2004). As for door dimensions, they should have a clear opening of at least 1m, preferably sliding, and corridors 1.2m minimum (Onion Mountain Technology, 2003).

Another feature of physical classroom design worth examining is the impact of the space on general students' performance and behavior. Experiment findings reported by Weinstein (1979) demonstrated that the classroom environment can affect non-achievement behavior and attitude (e.g. attendance, participation and enthusiasm) more than achievement (e.g. retention, learning and performance). Using different seating arrangements, e.g. rectangular, horseshoe, and straight rows also gave no significant differences for anxiety, number of acquaintances in the class, and social distance. On a separate note, open space classes (absence of interior walls) have shown increased teacher-student interaction, grouping, and individualized instruction but an increase in student achievement was not ascertained. However students with learning disabilities might be less able to function well in this situation, which is distracting, since student initiative and liability are stressed (Weinstein, 1979).

Students with attention deficit disorders and emotional disabilities often require greater physical and acoustical separation between activities to reduce distractions, making single-space classrooms inadequate for their needs. A more appropriate arrangement consists of versatile large common classroom areas with alcoves and different ceiling heights providing greater variety in a classroom's physical environment (Allen & Abbend, 2001). Colors have also been found to have a direct impact on these students who prefer very stimulating colors e.g. hot pink or fluorescent lime green. Students with reading disorders feel more comfort with blue hues, while autistic learners respond to yellow. Down Syndrome learners prefer red and visually impaired learners are drawn towards yellow text on navy or gray background (Onion Mountain Technology, 2003).

Regarding the effect of texture on perception of shape, research indicates that this can be hindered when the texture pattern is highly anisotropic, i.e. consisting of elements that are elongated in a specific direction (Interrante & Kim, 2001). Also 3D surface shapes may be perceived more accurately from line-like markings when lines of curvature of texture are followed (Li & Zaidi, 2000). Floor patterns may be used to visually widen or narrow a space, accentuate entrances, establish visual focal points on wall and floor surfaces and imply static or dynamic movement. In spaces for emotionally handicapped children, regular geometric patterns reduce visual stress and stimulate the brain. Inharmonious colors and irregular patterns disturb, distract and confuse such learners (Daggett et al., 2008). A general guide for utilization of colors proposes using pastels and softer colors for larger surface areas, but stronger brighter colors for smaller areas (Accommodation Standards, 2005). This is complemented by Daggett et al. (2008) who assert that warm colors can visually reduce space scale and size, whilst cool colors visually enlarge a space making it less confining. Furthermore, dark colors can visually reduce height of ceilings. Daggett et al. (2008) also recommend that classrooms incorporate a variety of colors (based on age, gender and activity) to decrease dullness, stimulate the brain and augment the attention span, but without overuse of color: more than 6 colors in a learning environment can strain the mind's cognitive abilities, cause eyestrain, glare and distraction.

Other specifications exist denoting plumbing regulations, parking, sanitary fixtures, furniture, accessories (e.g. door knobs and hinge openings), bus signs, storage facilities, and security systems etc., which do not apply in virtual worlds.

In accordance with the Assistive Technologies (AT) approach for design, elaborated earlier, Erdogan and Bayram (2007) examined the role of gender on legibility of online websites. Some discrepancies were found between males and females regarding preference for background-foreground color combinations online. The attitudes of female students towards the pages which have light text on dark ground were more favorable than those of male students.

As for the effect of age on designing for students with disabilities, the effect of wavelength was found to be stronger on younger subjects than older subjects. Older subjects have less trouble with shorter wavelengths than younger subjects, hence more affinity for cooler colors (e.g. blue, green with short wave lengths) than younger students. This may be due to yellowing of the lens with age. From about the age of 20, the human lens begins to absorb more light at all wavelengths, but it also absorbs relatively more short wavelength light (Flannagan et al., 1989; Saleeb & Dafoulas, 2010). This finding is further supported by Daggett et al. (2008) who affirm that younger students are attracted by warm, bright colors. With maturity, preferences change to bright medium-cool colors such as greens, blues, and green-blues (middle school) to darker colors (high school) such as burgundy, gray, navy, dark green, deep turquoise, and violet. Towards adolescence, there is less preference for large areas of primary color. Age can also cause decline in motor skills (e.g. slower response times, decreased ability to maintain continuous movements, disruptions in coordination and loss of flexibility). This may cause difficulty for older students to use input devices such as mouse and keyboard, being especially aggravated if student initially suffers from some sort of disability, hence causing difficulty in online interaction (Czaja & Lee, 2003). This may affect design considerations of 3D VLEs to minimize navigational skills required to and within 3D virtual learning spaces, by using for example less winding corridors and stairs, spacious dimensions etc.

All of the above researched evidence demonstrates the need and methods to customize the "real-life" physical space to provide accessibility and usability for students with different types of disabilities. The design factors referred to above were hence used, within this study, to provide the initial architectural design components to be tested and investigated for suitability within 3D VLEs for disabilities. This is essential, especially with the apparent absence of analogous studies depicting the effect of any of the aforementioned physical design elements as virtual design elements, on the e-learning experience of learners generally, and disabled students specifically, within 3D virtual learning environments.

RESEARCH RATIONALE

Elements of design taken into consideration for investigation within the research at hand were defined based on i) architectural elements researched previously in physical learning spaces (mentioned above) e.g. color, texture ii) components with currently available accessibility specifications (reported in the former section) e.g. ramps, corridors, lighting iii) architectural elements previously researched by the authors to have an impact on satisfaction of students, with no disabilities, in virtual learning spaces in 3D VLEs (Saleeb & Dafoulas, 2010d), e.g. architectural style, space shape and dimensions' ratio, seating arrangements, ceiling floor and wall textures and colors, greenery and water features, and percentage of open surface area.

A survey was conducted to capture the degree of satisfaction of adult learners with disabilities from the different architectural design features of 3D virtual educational buildings in Second Life as a representative of 3D VLEs. Participants included 76 volunteering users with disabilities constituting 3 groups of adult learners almost equally divided into under-graduates, post –graduates, and independent learners and researchers. Participants were "teleported" to each of 10 nominated educational facility sites, in sequence, inside Second life. The selected 3D virtual campuses were nominated since they contain a diversity of design elements that represent variations for 8 main identified architectural categories for

designing learning spaces (elaborated consequently). All partakers were initially immersed inside the required learning spaces in Second Life, during their blended learning sessions (i.e. whilst physically being in a real-life learning space). The students were then asked to answer 7 online Likert scale questions about how strongly they agree to the presence of certain architectural design elements in their 3D virtual educational spaces (strongly agree, agree, neutral, disagree, strongly disagree). It is worth noting that the participant sample contained disabled students from all five continents who also had diversified forms of disability (visual, hearing, mobility and cognitive), thus insuring generalization of the results. Furthermore, all participants were regular users of Second Life, one of the prominent 3D Virtual Learning Environments currently being used. This had the effect of eliminating from the results the effect of inexperience and intimidation, from the novelty of the virtual world, on the subjects' responses. After collection of the data online, the acquired numbers (representing students' preferences) were multiplied by predetermined factors to generate the overall percentage satisfaction of disabled adult learners from each design element as explained consequently.

The 7 questions were:

1. How strongly would you agree to the presence of the following *Architectural Styles* in your 3D virtual learning space?
   - Plain modern • Ornate classical • Futuristic • Mechanical
2. How strongly would you agree to the presence of the following *Colors & Textures* in your 3D virtual learning space?
   - Light colors • Dark colors • Soft colors • Bright colors • Smooth colors
   - Plain textures • Decorative pattern textures
3. How strongly would you agree to the presence of the following *Room/Hall Shapes* in your 3D virtual learning space?
   - Circle • Rectangle • Square • Polygon • Triangle
4. How strongly would you agree to the presence of the following *Space Dimensions* in your 3D virtual learning space?
   - Large height • Large width • Large length • Overall larger dimensions than RL
5. How strongly would you agree to the presence of the following *Environmental Features* in your 3D virtual learning space?
   - Interior water elements • Exterior water elements • Underwater theme
   - Between hills or mountains • Abundance of greenery
6. How strongly would you agree to the presence of the following *Lighting & Seating Arrangements* in your 3D virtual learning space?
   - Strong internal lighting • Extensively large windows • Open space • Semicircular / circular rows • Linear rows • Floating seats
7. How strongly would you agree to the presence of the following *Navigational Features* in your 3D virtual learning space?
   - Stairs • Ramps • Elevators • Flying to class via windows • Multi-storey / multi-rooms • One floor / single space • Removal of entrance doors

   To calculate the results, first the total number of student responses provided for each level of the Likert scale for each architectural digital design element was determined (e.g. 7 participants strongly agree that modern style is attractive whilst 2 partially disagree). This way it was possible to know the degree of satisfaction of the student body of participants from each variation of the tested architectural elements in this research. The resulting numbers were then multiplied by factors (weight), as follows, and an average was found thus giving an overall percentage of satisfaction for every 3D virtual architecture design feature:

((no. of "strongly agree" votes * 100%) +
(no. of "agree" votes * 66%) +
(no. of "partially agree" votes * 33%) +
(no. of "neutral"   * 0%) +
(no. of "partially disagree" * -33%) +
(no. of "disagree vote" * -66%) +
(no. of "strongly disagree" votes * -100%))

/ total number of participants * 100   (1)

According to equation (1) above, positive weighting factors indicate student satisfaction, whilst negative factors signify displeasure with the design element, where 100% denotes total satisfaction ("strongly agree"), 0% means indifference or "neutral" effect and -100% denotes total displeasure (strongly disagree). The 66%, 33%, -33% and -66% weights represent the even distribution of the other Likert scale values in between 100% and -100% based on importance. A similar data analysis method was adopted by Chan et al. (2004). The equation above was repeated for every architectural design element taken into consideration in the administered questionnaire.

Charts illustrating the different findings were then created to show the average percentage satisfaction scores per agegroup of adult learner participants (undergraduate students, post graduate students and independent learners/researchers), per disability type, per gender, and also their average as demonstrated in the following sections.. As elucidated formerly, this was done in an attempt by the authors to find individualized customization recommendations for enhancement of design of 3D virtual learning spaces in accordance with the AT design approach.

DISCUSSION OF RESULTS

The architectural design components tested for within the administered questionnaire were identified as part of either of 2 major divisions:
- Design elements related to or affecting the perspective of the 3D virtual learning space
- Design elements related to cognitive features in the 3D virtual learning space

Each of the above divisions contained 4 main categories of architectural design components into which the individual design elements were grouped as follows:

Perspective:
- Architectural style of the 3D virtual building (e.g. modern, classic)
- Space dimensions (e.g. ratio of width to length, large height)
- Space shape (e.g. circular, rectangular)
- Navigational features of the 3D virtual space (e.g. stairs, ramps)

Cognitive features:
- Colors and textures within the 3D virtual space (light and dark hues, smooth, rough textures)
- Environmental elements within or surrounding a 3D virtual space (e.g. water elements, greenery)
- Interior lighting level created by different percentages of open walls and roof
- Seating arrangements (e.g. curved, linear rows)

The satisfaction rates of the participants from each of the tested design elements, within each category above, were recorded according to the following three criteria:
- Based on gender of adult learners (male and female)

- Based on the major types of disability of the participant available (visual, physical and cognitive)
- Based on age group of adult learners (under graduates, post graduates and independent learners/researchers)

Diagrams depicting the resultant findings are illustrated in the following sections.

Effect of Gender on Student Satisfaction from Learning Space Design Features

Perspective Design features

Figure 1 below demonstrates that both male and female students showed a much higher preference for plain modern architectural building styles than any other style; and while females showed some tendency towards futuristic and, to a lesser extent, towards mechanical (blocky/angular) design, both genders revealed adverse affinity towards using classical design styles with elaborate and intricate details. This is probably due to the simplicity of modern design style with non-presence of cluttering ornate details that can be distractive during the e-learning process or non-appealing for the male student population in particular who tend towards practicality by nature. This is in addition to the extra lag in the online connection that can be experienced due to loading and "rezzing" of the extra elements and fine details added. However unexpectedly, females showed more flexibility than males towards experiencing other innovative style designs in 3D virtual worlds, e.g. futuristic and mechanical styles, which are non-conventional styles for educational facilities in the physical world; though the general low popularity of the futuristic designs indicate general preference of users for more realistic designs during e-learning that they can relate to like in "real-life".

[INSERT FIGURE_ONE HERE]

Figure 1.Percentage satisfaction of male and female adult students with disabilities from architectural design elements related to perspective in 3D virtual learning spaces

Regarding student satisfaction from learning space dimensions, figure 1 shows an identical resemblance between order of preference for space dimension factors by both male and female participants. Despite the difference in the satisfaction percentage values between males and females, they both affirmed highest recommendation for large/ increased heights, followed by an increase in width of space, an overall increase in dimensions, and lastly an increase in the length of the space. Enlarging the space height is necessary to accommodate for camera control manipulation "in-world", flying of avatars and for reduction of sound travel from storeys above or below. This is a concrete difference with the physical world, where ceiling heights rarely go above 4-5m, whilst in virtual worlds many designers prefer to have ceilings at least 7m in height. The increase in width and length of the space dimensions can be attributed to allowing ease of navigation of the avatars in the virtual space which can present difficulty for students with disabilities to have sufficient hand control skills to manipulate the avatar movement.

Figure 1 further demonstrates disparity between male and female preferences towards internal space shape, where highest female student preference was towards rectangular and square shapes unlike male students whose highest preference was towards the circular shape but with considerable agreeability towards the square followed by rectangular shape. Both genders showed displeasure towards triangular space shape. Conversely, little research analogously investigates the effect of the shape of the learning space on the student's learning experience in the physical world, however an early study reports that the square shape can be considered one of the simplest to learn, understand and perceive compared to multi sided polygons for example (Attneave, 1957), which might offer an explanation for the high affinity of students towards square and rectangular shaped spaces.

Satisfaction of all students from different navigational components, as evident from figure 1, fluctuates considerably between high favoritism of both male and female participants for employment of ramps,

usage of one floor single spaced learning facility, and removal of entrance doors, as opposed to negativity towards using stairs, and multi-storey, multi-room educational buildings. This is due to the ease of navigation of avatars along 3D virtual ramps versus the difficulty of management of avatars up narrow 180° winding stair flights which need proficient mouse control skills to prevent the avatar from falling off and maintaining a straight course. Non-presence of entrance doors to spaces can also allow smooth avatar motion and provide a more comprehensive view of the interior thus better perception of the 3D virtual learning space. Utilization of one storey / single space 3D venues is also a necessity to prevent hindrance of avatar movement control due to relocation from one corridor, room or floor to the next having to pass round many walls in the process which again requires adept mouse skills on the user's side. Multiple small spaces also impede the ability to perceive the 3D virtual space perspective adequately on screen due to difficulty of manipulating the "in-world" control cameras in confined spaces. Usage of elevators to travel between floors was somewhat agreeable by both males and females. This is because even though it does not involve moving up winding stairways, there is still a considerable amount of maneuvering required to adjust the avatar's orientation inside a lift and press appropriate controls to reach destination which for some students with disabilities can be cumbersome. As for flying up to class through the space windows, this was more highly appreciated by male students than female students maybe due to the physical and adventurous nature of males.

Cognitive Design features

Figure 2 demonstrates higher contentment rates offered by students from both genders towards lighter colors than dark hued colors, and towards cooler colors than bright warm hues. Both male and female students also almost gave identical percentage satisfaction rates for smooth and plain textures which were more highly regarded than decorative pattern textures. These findings coincide with previous literature depicting physical world color preferences, which indicate that cool colors visually enlarge space perspective, and dark colors visually reduce height of ceilings which is non preferable in 3D VLEs as specified earlier. Decorative and patterned textures have also been known to cause distraction during the learning process in physical learning spaces, and thus can be expected to have the same effect in 3D virtual learning spaces thus contributing to the attained results.

There is lack of research portraying effect of internal and external environmental features on students' satisfaction from their learning sessions in both the physical and virtual worlds. Figure 2 illustrates that male students showed high regard for presence of water elements inside and outside the learning space (e.g. fountains, lakes, surrounded by sea). They also encouraged a change in the surrounding terrain gradient to duplicate presence between hills or mountains. This can again be attributed to the adventurous, physical nature of males. Females on the contrary showed no specific inclination towards any environmental feature in particular, with slightly more agreeability towards presence of exterior water elements and greenery / vegetation which was also equally regarded by males. As for creating buildings under water, female students preferred this theme more than male students.

[INSERT FIGURE_TWO HERE]

Figure 2. Percentage satisfaction of male and female adult students with disabilities from architectural design elements related to cognitive features in 3D virtual learning spaces

Regarding lighting preferences, findings from figure 2 show that male learners favor a high percentage of strong internal lighting which accordingly requires large areas of open walls and windows, or completely open space. However while female learners supported usage of large window areas, they were not in high favor of taking e-learning sessions in completely open spaces. This may be due to the more conservative nature of females which requires more secure surrounding borders for the space to also diminish distraction during the e-learning process from exposure to the outside environment.

As for seating arrangements, semi circular and circular rows were highly preferred by males, whilst linear rows were unfavored. This is contrary to female inclinations which appeared neutrally equal

towards both curved and linear row arrangements. However both genders refused usage of floating random seats because of the added sense of insecurity and instability accompanying floating above ground, which indicates preference of students for seating arrangements that emulate those in "real-life".

Effect of Type of Disability on Student Satisfaction from Learning Space Design Features

Perspective Design features

[INSERT FIGURE_THREE HERE]

Figure 3. Percentage satisfaction of adult students with different disability types, from architectural design elements related to perspective in 3D virtual learning spaces

Figure 3 illustrates that adult students with visual and cognitive disabilities almost only favor plain modern architectural style for design of learning spaces with little, almost null or adverse affinity towards classical, detailed, futuristic and mechanical styles. This is due to the fact that classical intricate details in design can be distracting during e-learning especially for students with attention disorders, or exhausting and eye straining for students with visual disabilities. However students with cognitive disabilities also showed considerable flexibility towards futuristic, imaginative styles, probably corresponding with their specific meditative, perceptive and mental needs. Participants with physical disabilities also gave higher preference for modernistic style than classical style but satisfaction rates were within close range.

Regarding contentment from space dimensions, large height was the foremost recommendation by students with physical and cognitive disabilities. Students with physical disabilities in general favored increased width, length and overall dimensions of the 3D virtual space. This can be attributed to the necessity of spacious areas to alleviate the effect of users' problems with manual dexterity which makes it difficult to manipulate avatars' movements and control the "in-world" camera views in small spaces. Students with visual disabilities mostly favored deployment of large space width, which can help widen the view angle of the space to augment the perception of the virtual space perspective to counteract for visual ability problems.

As evident from figure 3, students with visual and physical disabilities highly favored square and rectangular shaped spaces, with negative satisfaction rates towards other shapes especially circular. One reason can be due to increased connection lag with use of more "prims" for circular shapes. Another reason could be that square shapes define the space more clearly especially for users with visual disabilities, thus providing better understanding of the space perspective; this is besides allowing easy navigation along 4 specified axes instead of in a curved manner which renders avatar movement easier for users with physical dexterity disabilities. Students with cognitive disabilities on the other hand preferred circular shaped spaces since the non presence of distinct wall edges can give a smooth continuation effect for the space and spaciousness which might have a more comforting impact on learners with cognitive disorders.

As for satisfaction from navigational components of the 3D virtual learning space, adult students with all types of disabilities preferred usage of ramps, especially students with physical disabilities who might be using ramps for ease of accessibility of wheelchairs in "real-life" and thus feel more comfort with presence of ramps in the virtual world to relate to their reality even if their avatars are not disabled in VEs. Conversely, utilization of stairs was negatively advocated and elevators poorly regarded since these require good avatar manipulation which might not be available for users with motor disabilities in hands and fingers. Removal of entrance doors, or at least keeping them open, was considered by all students more convenient for navigation without using scripts to open them on touch. Flying to class directly through windows was moderately favored by users with physical disabilities: this requires large windows with phantom texturing (i.e. penetrable) thus facilitating navigation for these students. One very important requirement by all students was to make buildings contain one single open space not several

storeys, again to ease navigation of avatars inside them and minimize the connection lag due to presence of many loadable objects or "prims" if multiple rooms were built.

Cognitive Design features

As displayed by Figure 4, the greatest color and texture preferences by all adult students were for light and cool colors as opposed to dark or bright/warm colors; also plain textures rather than patterned textures. In accordance with previous literature findings of the effect of textures on learning in the physical world, utilization of plain textures is particularly assistive in reducing distraction during e-learning in 3D virtual spaces for users suffering from attention deficit disorders. Smooth textures were also favorable by all categories of disabled students. However while decorative patterns and dark hues were definitely disagreeable, bright colors were somewhat acceptable by students with visual and physical disabilities. This is partially consistent with literature findings in the physical world which depict preference of some users with cognitive disorders for very stimulating colors (e.g. hot pink, fluorescent lime green, or red for Down Syndrome learners), even though other students with e.g. reading disorders feel more comfort with blue hues, and autistic learners with yellow i.e. cooler colors, which is recommended here for 3D VLEs.

Regarding satisfaction from environmental design elements, preference of users with all types of disabilities is apparent for water elements, e.g. fountains etc., on the exterior of a building rather than inside the learning space. This can be attributed to the distracting effect of these decorational elements inside the learning process. Unexpectedly, there is very little affinity towards using greenery or vegetation. This can be due to presence of greater connection lag to rez these elements, and because they can obstruct vision of builds behind them if abundant, and also can obstruct navigation of avatars by flight. Unexpectedly also, students with physical and visual disabilities recommended using underwater designs. However students with cognitive disabilities affirmed adverse empathy towards this theme due to increased emotions of claustrophobia, confinement and asphyxia experienced by feeling submerged underwater.

[INSERT FIGURE_FOUR HERE]
Figure 4. Percentage satisfaction of adult students with different disability types, from architectural design elements related to cognitive features in 3D virtual learning spaces

Figure 4 further shows that extensive use of windows and internal lighting was favored among all groups of users. Use of open space for a learning venue was only high in demand with visual disabilities, to add increased visual stimulation for these users thus enhancing their e-learning experience. However this was less favored by students with cognitive disabilities as this increases the distraction from the open surroundings for these users during an e-learning session.

Concerning seating arrangements, semi circular arrangements and linear row arrangements were both equally regarded except by cognitive disability students. Floating seats were not desirable which is consistent with the former undesirability of fantastic/ space like design styles of building.

Effect of Adult Students' Age Group on Satisfaction from Learning Space Design Features

Perspective Design features

Figure 5 reveals that all adult students with disabilities, from different age groups, expressed highest satisfaction rates towards using simple modernistic architectural design style, and complete discontentment from ornate classical styles; with independent learners and researchers being more flexible towards using futuristic imaginative styles in design of 3D virtual educational facilities than under and post graduates.

Furthermore independent learners and researchers favored an increase of space height as the highest recommendation for enhancing space dimensions, while under and post graduates recommended an increase in space width.

As for space shape, under and post graduate adult students showed no interest in circular and polygonal shapes with highest favoritism for rectangular and square shapes. Independent learners' highest affinity was towards all three shapes, namely, square, rectangle and circle. All adult student age groups disregarded the triangular shape.

Percentage satisfaction of students with disabilities from navigational components illustrated similar findings to former results, with ramps, one floor/ single space, and removal of entrance door being the highest elements in demand for all adult student age groups. These were followed by flying to class and use of elevators. Employing stairs and multi-storey / multi rooms in the 3D virtual space was highly unfavored.

Cognitive Design features

Unexpectedly, as evident from figure 6, percentage satisfaction of under and post graduate students was almost identical for all types of color hues and textures, with a slightly higher inclination towards light colors, but with definitive dissatisfaction from decorative patterned textures. This indicates a great variation in personal taste and accessibility requirements between the students. On the other hand, independent learners and researchers displayed highest tendency towards light colors, cool colors and plain textures.

Unexpectedly also, was the reaction of under and post graduate students with disabilities towards environmental features, which seems to be mostly neutral towards most tested environmental features, with the exception of exterior water elements and moderate demand for presence of greenery and vegetation (e.g. trees, flowers, shrubs). In contrast independent learners showed considerable favoritism for all environmental design elements, especially exterior water elements.

Regarding contentment from lighting, under and post graduate adult students mostly preferred open spaces for e-learning venues, contrary to independent learners and researchers who required strong internal lighting and extensive areas of windows. This might be due to a more conventional viewpoint adopted by the latter group of adult learners preferring a virtual e-learning environment similar to that in the physical world.

As for seating arrangements, independent learners and researchers highly recommended usage of semi-circular/ circular rows. Under and post graduates equally recommended curved and linear rows. However all age groups unfavored using floating seats.

[INSERT FIGURE_FIVE]
Figure 5. Percentage satisfaction of different age-grouped adult students with disabilities, from architectural design elements related to perspective in 3D virtual learning spaces

[INSERT FIGURE_SIX HERE]
Figure 6. Percentage satisfaction of different age-grouped adult students with disabilities, from architectural design elements related to cognitive features in 3D virtual learning spaces

Overall Percentage Average Response of Adult Students with Disabilities to each 3D Learning Space Design Feature

Figure 7 below depicts the average percentage response rates supplied by adult learners from each gender, disability type and age group for each category of architectural elements on the whole, in an

attempt to uncover which architectural design categories are most important to students to achieve satisfaction during e-learning.

This gives an indication to which architectural design elements should be taken into consideration first by designers during the process of building educational facilities in 3D virtual worlds.

[INSERT FIGURE_SEVEN HERE]

Figure 7. Average percentage satisfaction of adult students with disabilities, from the overall categories of architectural design in 3D virtual learning spaces – according to gender, disability type and age group

With regards to gender, it can be seen that highest positive response rates were provided for navigational features of the 3D space by both males and females, indicating that accessibility factors of the 3D virtual space are vital for students with disabilities. Figure 7 further shows that males equally regarded lighting and seating arrangements, environmental features, space dimensions and colors and textures, while space shape and architectural styles seemed least significant. As for females, colors and textures came in second place after navigational features. Environmental features and space shape came in last place which was an unexpected result.

Highest positive response rates offered by adult learners with visual, physical and cognitive disabilities were also given for navigational features, closely followed by colors and textures, lighting, and seating arrangements. Again here, space shape received least positive votes, followed by architectural style, environmental features and space dimensions.

As for age group division, the highest percentage of positive votes was also given for navigational features and colors and textures. Least combined positive votes were for space shape, but least percentage, presented by under and post graduates, was for environmental features.

The above findings reveal that the most significant architectural design categories identified by the students were a combination between those related to perspective, and cognitive features in the 3D virtual learning space i.e. navigational features, colors and textures, lighting and seating arrangements. Recommendations can hence be issued for enhancement of 3D virtual learning space design by primarily concentrating on developing the formerly mentioned prominent categories of design, followed by all other categories of 3D architectural design: space dimensions, architectural styles, environmental features and space shape.

Solutions and Recommendations

As previously elaborated, results within this study offer customized recommendations, for enhancement of the 3D virtual learning space design for adult students with disabilities, based specifically on gender, type of disability and age group, thus adopting a more individualized technique for enhancement of the e-learning experience using an Assistive Technology approach. In reality, both the individual view (AT) and the environmental view (UDL) are essential. Focusing solely on the design of AT, will inherit an environment that is poorly designed. On the other hand, focusing only on universal designs at the exclusion of AT, will fail to consider the customized adaptations that many people need and will build environments that are either not efficient for individuality or too complex and expensive to be individually customized. Hence, Assistive Technologies make Universal Designs more effective. Designs that integrate both approaches emphasize the fact that disabilities are defined by the interaction between the environment and the individual (Rose et al. 2005; MacArthur et al., 1990). This study, while being part of a more comprehensive research contemplating both approaches, is essentially focused here on highlighting the AT design approach.

FUTURE RESEARCH DIRECTIONS

Future research involves exploring effects of culture and background educational fields of students on the results. Future work also includes measuring actual effects of the design elements on students' retention rates, enjoyment and participation during e-learning sessions. Additionally, documenting other virtual worlds' designers and architects guidelines, to build for users with disabilities, can shed more light on best practices for designing accessible 3D virtual learning spaces in 3D VLEs.

CONCLUSION

This research investigated satisfaction rates of adult students with disabilities from different architectural design elements of 3D virtual learning spaces. This helped issue recommendations for design enhancement of these spaces to achieve better usability and accessibility for users with disabilities, hence improving the overall blended (physical and virtual) learning experience.

The attained results include general design propositions such as

- Usage of modern architectural style
- Increase of space height and width
- Utilization of square and rectangular shaped spaces
- Usage of ramps, and single storey/single space buildings
- Employment of light, cool colors, and smooth, plain textures for surface finishing
- Abundance of exterior water elements
- Use of extensive window areas to produce a sense of strong internal lighting
- Creation of curved rows for internal seating arrangements
- Emphasis in design on the navigational aspects of the space which is the most significant category voted for by the participants

Findings within this study also provide customized design propositions based on gender, type of disability and age group of adult learners. These can be used to initialize a framework of codes, guidelines and specifications for designing 3D virtual educational facilities and learning spaces in 3D virtual learning environments, with special attention to usability and accessibility for users with disabilities. This framework would be complementary to its counterpart in the physical world for designing "real-life" educational facilities.

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KEY TERMS & DEFINITIONS

2D Virtual Learning Environment: An online software system with a website interface containing tools to support learning

3D Virtual Learning Environment: an online environment that can be used for learning, created in 3 Dimension where users can move, build, communicate using created 3D characters

ADHD - Attention deficit disorder: a condition (mostly in boys) characterized by behavioral and learning disorders

Architectural Design Guidelines: These are the different codes, specifications and rules used to design a building

Autism: An abnormal absorption with the self marked by communication disorders and short attention span and inability to treat others as people

Avatar: 3D character which the user creates to login and use a 3D virtual environment
Cerebral Palsy - a loss of motor control with involuntary spasms caused by permanent brain damage present at birth

Dyslexia: A learning disability that manifests itself as a difficulty with reading decoding, reading comprehension and/or reading fluency

In-world: A term meaning being logged into the 3D virtual world

Rezzing: A term referring to the process of appearance or loading of objects inside a 3D virtual environment

Second Life: a 3D virtual world, accessible via the internet where users can socialize, customize an avatar, connect and create using free voice and text