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WHAT LEARNERS WANT FROM EDUCATIONAL SPACES? A FRAMEWORK FOR ASSESSING IMPACT OF ARCHITECTURAL DECISIONS IN VIRTUAL WORLDS

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ABSTRACT

In this paper we provide a revised presentation of our investigation of how architectural digital design elements of virtual worlds affect learning experiences. The paper provides an initial reflection on learners' requirements for 3D virtual worlds. Emphasis is given on determining a typology of learning requirements affecting the design of 3D Virtual Learning Environments (VLE). In particular, the research study focused on 3D virtual educational facilities and their impact on learning experience in comparison to real life in-class experiences, by introducing optimum 3D virtual world features in spaces, and turning them into learning places. Emphasis is given on how a range of learning objectives affect design efforts in virtual worlds intended for supporting learning activities. Examples of how virtual worlds may transform learning experiences include information retention, participation and enjoyment. The paper considers design elements that have a causal effect to such learning objectives and considers what design recommendations could be used to enhance the student's overall learning experience in 3D VLEs. The paper investigates the impact of architectural design guidelines in relation to several features including space shape, size dimensions and height, interior lighting and open walls, colours, textures, floor, wall and ceiling design, architecture style, window design, seating arrangements, and building entrance.

KEYWORDS

Virtual Worlds, Second Life, 3D Virtual Learning Environments, architectural design, educational virtual spaces and places, learners' needs

1. INTRODUCTION

The investigation of virtual learning worlds in education has been the focus of a well-established community of researchers with a substantial volume of published works. The authors have been investigating the interception of pedagogical and design issues of 3D virtual worlds for more than a decade in an effort to contribute guidelines for optimum use of learning spaces in the Second Life platform. On going research also aims to identify good practice and establish feasible learning processes that use 3D virtual learning spaces effectively.

Typically, the relevant literature is focused primarily either on providing overviews of available platforms and their features or presenting findings from specific cases of using 3D virtual learning worlds. In this paper we focus more on evidence from the literature on how such learning spaces improve the learning experience of students. Our claim is that there is sufficient literature volume advocating and proving that effective use of 3D virtual worlds enhances learning experiences and improves learners' results. Our contribution is in the form of design practices that improve the impact of 3D virtual learning worlds.

According to Kostantinou et al (2009), who developed a a 3D virtual environment with the use of OpenSim for a high school in Greece, student results were dramatically increased with the use of the virtual environment (average of 74%) compared to the results of students who prepared in a more traditional ICT-supported session delivered with the aid of power point presentation (average of 56.5%) and students who did not receive any support prior to the test (average of 35%). Their focus was on comparing the impact of two learning experiences on learners' performance, "one that takes advantage of the new environment in order to attract students' attention and increase their collaboration and one that combines traditional teaching methods with modern ICT" (Kostantinou et al, 2009). We firmly believe that effective use of 3D virtual worlds can improve assessment results and enable the creation of more engaging and supportive pedagogies (Saleeb and Dafoulas, 2013) (Saleeb et al, 2013).

The work of Braun et al (2014) has identified "the necessity of providing more guided routes through the learning process (e.g., in order to make pedagogically useful choices of material and to select appropriate tasks)". Scholars identified five learning strategies developed by students in their practice sessions, identified as (i) Setting aims for the interpreting practice session, (ii) Preparing for the interpreting assignment, (iii) Adapting to the selected content, (iv) Reflecting on the interpreting assignment and (v) Self-evaluation. We think that the development of such strategies is further enabled by virtual world designs that take under consideration how the learning space may act as a centrifugal or even as a centripetal force for the learning process.

An interesting aspect of existing work is the evaluation of different educational aspects associated with the development of virtual worlds. Kostarikas et al (2011) have used five criteria for assessing their environment based on an integration of Second Life with the Moodle Virtual Learning Environment (VLE) focusing on students' perception on triggering student excitement, attracting student interest, offering improvement from real life class settings, improving level of understanding and offering a helpful learning tool. Similarly we have organised our evaluation of our 3D VLE according to a number of architectural aspects in an effort to map the impact of each architectural feature to particular learning processes.

This paper revisits previous work in an effort to provide a research method for collecting and analyzing data on virtual worlds used for educational purposes. The paper's scope is twofold (i) to provide a set of guidelines for a multi-stage research approach in investigating how 3D worlds' educational features can be used for enhancing e-learning activities and (ii) to discuss the findings relating to the impact of various architectural features in the effectiveness of 3D virtual learning environments. Therefore the paper first provides a step-by-step approach that can be adopted when assessing the impact of 3D virtual worlds in education. Instructors can follow the proposed guidelines in order to investigate whether their architectural designs are able to turn learning spaces into learning places (i.e. environments that effectively support the learning process). The paper also provides an overview of detailed findings determining design decisions towards an effective learning environment in a 3D world setting. It is however expected that the recommended architectural decisions may need adjustment depending on the learning scenario, the number of participating learners and the use of the learning space.

The work presented in this paper provides a concise summary of data collection practices over several years in multi-disciplinary area. The authors focused on various aspects from three areas of work, namely education (in particular e-learning practices), architecture (emphasis on specific elements of learning spaces) and Information & Communication technologies (ICT) and their role in supporting learning activities. Second Life was the platform of choice at the beginning of this study and is currently used, as there is a significant infrastructure that supports learning activities. The benefit of bridging the gap between the three disciplines was the provision of a holistic view of the problem associated with learners' needs in 3D virtual worlds. It has allowed us to consider how architectural decisions would support various types of learning activities and educational needs, while maintaining high level of support as provided in traditional ICT-enabled learning processes and VLEs.

Initially this work was concerned with the ways virtual world environments affected student satisfaction, and in particular the role of architecture in 3D education (Saleeb and Dafoulas, 2011). The research followed a more detailed investigation in the way 3D learning spaces enhance e-learning experiences and how certain design measures can help improving learning experiences (Saleeb and Dafoulas, 2012). An interesting twist of previous work involved considerations in how Artificial Intelligence (AI) could be used for supporting e-learning pedagogies with the use of 3D Virtual Learning Environments (VLE) (Saleeb and Dafoulas, 2013). Most recent work focuses on ubiquitous learning and personalization of 3D learning spaces for improving learning experiences (Saleeb et al, 2015). Our work has evolved from assessing the way 3D virtual world platforms support learning activities into reshaping educational support tools by reconsidering pedagogies for 3D VLEs, reflecting on the support requirements for online communities existing in virtual worlds and providing guidelines for instructional design.

2. LEARNERS' NEEDS FROM 3D VIRTUAL WORLDS

During the earlier stages of our research we attempted to assess learners' needs by conducting surveys with the participation of VLE users. There was a fundamental issue with this approach that was very common in the research field as learners' needs are different when immersing in a 3D learning world. As virtual worlds were in their infancy in the early 2000s, it was impossible to find learners with significant experience in the use of 3D virtual worlds in learning contexts. Several years later, there are numerous examples of 3D virtual worlds being used in a wide range of learning settings. It is therefore possible to assess key requirements learners have from such learning spaces.

An interesting challenge when using virtual worlds in an educational context is finding how to address the difficulty in projecting social and emotional communication with both students and teachers that virtual courses have. A lot of work has been done in "allowing students face to face meeting in which students can see each others avatars and use the different gesture commands to communicate", use of customized gestures and voice communication (Barkand and Kush, 2009). The focus of such work is on creating an online learning community in the virtual world and replicate social aspects of learning as they tend to be one of the key requirements learners have when they shift from the traditional classroom to the virtual learning world. This is why our work has aimed to assess the impact architectural features having when replicating real-world learning spaces in virtual worlds or when designing learning spaces directly for 3D VLEs.

Advocates of learning enhancement via 3D virtual worlds focus on the concept of "encoding specificity" meaning that "a learner will be better able to remember what he/she has learned if the conditions during learning match those during recall" (Maratou et al, 2015). According to Maratou et al (2015) "virtual worlds can provide learners with a full understanding of a situation using immersive 3D experiences, which allow the learner to freely wander through the learning environment, explore it, obtain sense of purpose, act, make mistakes, collaborate and communicate with other learners". Our work emphasis the importance of aligning design elements of 3D learning spaces to the learning activities supported by the specific environments.

It is important to note that there is some work investigating the effectiveness of virtual worlds for collaborative design learning. In particular, Gu et al (2009) investigated the "application of virtual worlds in both technical and procedural experiences, and discusses the benefits and shortcomings of virtual worlds on design education". They have worked on the quantitative analysis of architecture students and provided evidence for some groups that "have demonstrated a very high level of competency in applying and adopting 3D virtual world features for different design phases". These findings helped us to realize that the use of 3D virtual world features can improve learning not only on collaborative design scenarios but also across other educational areas.

Interestingly enough, part of the relevant literature focuses on the quality of learning spaces in 3D virtual worlds and the development of a space into a place. According to Mavridis et al (2012) "architectures transform not only a space but the patterns of activity for those who occupy them". These patterns can be viewed along five polarities: a) movement – stasis, b) interaction – isolation, c) publicity – privacy, d) visibility – hiddenness, and e) enclosure – exclusion. Their work that consists of two primary phases of familiarization with the environment and the specialization with the learning tasks provides a research study process similar to the one presented in this paper.

Ibanez et al (2011) have reviewed a range of learning possibilities with the use of 3D virtual worlds, focusing on their impact on language learning scenarios. The different learning possibilities within 3D VLEs include (i) situated learning (Ertmer, and Newby, 1993), (ii) role playing (Holmes, 2007), (iii) cooperative/collaborative learning (Chittaro and Ranon, 2007), (iv) problem-based learning (Jonassen, 1994) and (v) creative learning (Huang et al., 2010). This classification is in line with our views on the different types of learning activities that can be supported through an effective learning space that is based on sound architectural designs of 3D virtual worlds.

According to Skold (2011) "learning space, both physical and virtual, is compounded by numerous properties, such as lighting, room size and layout, color, arrangement of furniture, and acoustics. Even though there is a consensus that learning space decidedly affects learning, the methodological question of how to perform individual analyses of the properties of space is often viewed as one of the major difficulties". Based on the literature review on physical space and learning, Skold (2011) various properties including colour and seating arrangements have an effect on learning. Findings from the literature review on architecture and virtual space provided evidence that virtual space architecture plays an important role in supporting the emergence of a “sense of place” among students, which is beneficial for learning.

In summary, learners’ needs in 3D virtual worlds could be classified under the following types:

- The need for sensing that they belong to an online learning community.
- The need for engaging in social and emotional communication as part of learning activities.
- The need for an immersive learning experience helping the ‘learning by doing’ paradigm.
- The need for supporting a range of learning activities and different learning settings.
- The need for architectural features that facilitate learning activities in 3D virtual worlds.
- The need for spaces designed in a way that transforms them into learning places.

Our paper discusses in detail how we have focused on these needs, and primarily on the last two types in assessing how architectural decisions impact learning in 3D virtual worlds.

3. RESEARCH METHODOLOGY

As mentioned in the introductory section, the research study was based on collecting information about the impact certain 3D virtual world architectural features would have in the learning process. It was imperative to follow an approach that would be based on different techniques in order to ensure the accuracy of the investigation results. Within the research discussed in this paper, data collection is divided into four (4) phases, each with a definite objective, conducted using different methods, to feed its results into the next phase and help design it. The mixed method choice was deemed ideal in order to collect information by observing learning scenarios, collecting users’ experiences and consulting experts in the field. The research strategy was based on a mixture of grounded theory, experiments and surveys. Overall our inductive approach is in line with the interpretivism philosophy, as we attempted to collect and analyse data from a series of learning settings in order to understand the realities of 3D virtual world learning.

3.1 Sequential Research Phases

The **first phase** of the data collection involved survey questionnaires consisting of a number of closed-ended questions which were distributed, after pilot trials involving students, in order to record participants’ opinions about different architectural design characteristics in different existing 3D virtual learning spaces that the students are subjected to in Second Life. Furthermore open-ended survey questions were used to capture students’ propositions and requirements from the design of 3D educational facilities. Interviews and focus groups with students and staff were then used for validating the previous results. This phase was designed in a way to derive how learners experienced the different architectural features of the learning space within the virtual world. Statistical conclusions derived from these quantitative methods would preliminarily verify the presence of an effect for 3D architectural design elements of learning spaces on students (proving the deductive hypothesis within this research), and also highlight some of the more appreciated or depreciated features of design to be taken into consideration in the next phase of data collection. It is obvious that this first stage is feasible for most research studies, as far as the researchers are able to follow a questionnaire design process and have the skills to analyse responses, as well as triangulate data collection with the use of additional techniques (e.g. focus groups and observations). The objective of the first phase was to collect and analyse the learners' perception of the learning space in relation to the impact of specific architectural features on their learning experience. The benefit of this stage is that it can be replicated and adapted for a variety of learning settings, as well as offering a straight forward data collection approach that does can be conducted from researchers who wish to conduct a small-scale experiment. The main drawback of thie first phase is that it depends on the participants' demographics, as its focus is on the impact of architectural features that may be less

The **second phase**, was based on controlled quantitative experiments conducted after pilot trials inside Second Life, as a representative of 3D VLEs, where only one independent variable per experiment is changed e.g. colour, texture, shape of space, dimensions. This approach provides an opportunity to engage in observations through pilot studies with end users. This technique provides an alternative way to determine those architectural features that have a significant impact on the learning process. The focus is on a selection of variables that should be tested which are determined based on (i) most appreciated 3D virtual design elements recorded during the first phase, and (ii) the element to test must be previously researched for its effect on learning in the physical world. During this phase, students were placed inside this controlled environment, and after taking an e-learning session inside it while changing the attributes of this controlled variable several times, quantitative survey questionnaires were collected to depict students' opinions and feelings throughout the session towards different variations of the variable (e.g. different shapes, different colours). Qualitative video and audio recordings were also taken of the sessions to be analysed for validation of findings and for further extraction of student satisfaction or dissatisfaction evidences towards different design elements. Findings from this phase should determine best and worst variations, of each 3D architectural design element, to be used in the final phase (phase 4) to test their measured effects on the e-learning process. The objective of the second phase was to retrieve different types of data from controlled experiments. The main benefit of the stage is that it provides the opportunity for triangulation as the controlled experiments provide findings in the form of participant responses, as well as observation videos and images. The main drawback of the stage is that is based on collecting responses fro participants who may not be able to experience but a few variations of architectural features, due to the limited duration of each pilot study.

The **third phase**, is concerned with the triangulation and validation of findings from students' data in phase 2, which is done through performing individual interviews with experts in the field (educational staff and 3D architectural designers and architects). The phase aims to derive what practical guidelines they utilise for designing 3D virtual educational facilities and what feedback they know from experience with students about their requirements from architectural design of their 3D learning spaces. This is a critical stage as it aligns primary data representing findings from pilot studies and surveys with end users to the views of experts. The techniques used offer a reality check as it can be used to compare own research findings with the views of experts and other practitioners. The objective of this phase was to align the findings from non-expert participants to the responses of experts who should assist in assessing the impact of specific features. The benefit of this phase is that it ensures that data collection analysis is validated when they are in line with expert views. On the other hand the phase requires access to a significant number of experts to ensure that they provide a representative sample of the field's state of the art.

The **fourth phase**, of data collection provides a qualitative approach as it involves conducting controlled qualitative experiments involving students who receive an e-learning session inside a learning space, that is a predesigned prototype in which only one variation of one architectural feature is applied per experiment (independent variable). This experiment is repeated for two variations of each architectural element identified and chosen during phases 2 & 3. This technique is very important in order to obtain an understanding of the impact specific architectural features have for specific learning experiences. These experiments are then repeated with different groups of students. This is also necessary to establish a good understanding of how each feature impacts learning with the involvement of a significant number of subjects. It is also necessary to reflect on whether the effects of architectural features are the same across different learning groups. The two chosen variations of each tested element are what phase 2 results initially show as being the best and worst preferred by students for that design element. This is done to capture the change or effect these variations have on the e-learning process itself, by measuring students' retention (understanding), participation and enjoyment during each experiment. One of the key contributions of this research study has been the proof of impact towards these three concepts associated with learning experiences of students. The objective of this phase was to test the impact of specific architectural features by isolating design variables during learning activities. The benefit of this approach is that it provides a controlled experiment setting that is concerned with specific features of 3D world design. The main drawback of the phase is that it does not guarantee that participants' perceptions are not affected by other external factors.

In terms of applying the proposed method, it is important to clarify that when one experiment is completed with all groups of students, the next experiment with another design element variation is performed with the same groups of students. This means that each experiment goes through a sequence of element testing with the same cohort. Besides measuring experiment outcomes, sessions inside Second Life are recorded audio visually to be transcribed and examined. The authors found that having a detailed archive of recordings from all experiments allowed them to put their quantitative results in perspective by observing the behavior of avatars during each learning session.

During the final data analysis phase, from all surveys, controlled quantitative and qualitative experiments, and interviews the authors determined which architectural design elements have an effect on a student's e-learning experience, and what the extent of that effect is with specific variations of that design element. This helped initiating a framework of guidelines, for 3D architectural design of educational buildings, inside 3D virtual learning environments.

3.2 List of Proposed Research Steps and Corresponding Outputs

The sequential research process described above provides a structured approach towards the collection of primary data for the impact of architectural features in e-learning experiences using virtual worlds. This research study was based on using a series of pilot studies and various data collection techniques involving learners, instructors and experts. The authors have presented their findings widely and applied them in different learning settings such as undergraduate and postgraduate cohorts, distance and blended learning modes, higher and further education programmes, educational programmes and continuous professional development short courses, university classes and training sessions. The aim of the proposed series of data collection steps was to establish a set of guidelines for good practice that could be used by practitioners and researchers in various fields. The approach could be used in the same field that is the experimentation with virtual world environments, related areas such as e-learning, mentoring, teaching and instruction-centred design, but also in the wider research context of data collection through application, observation and surveying.

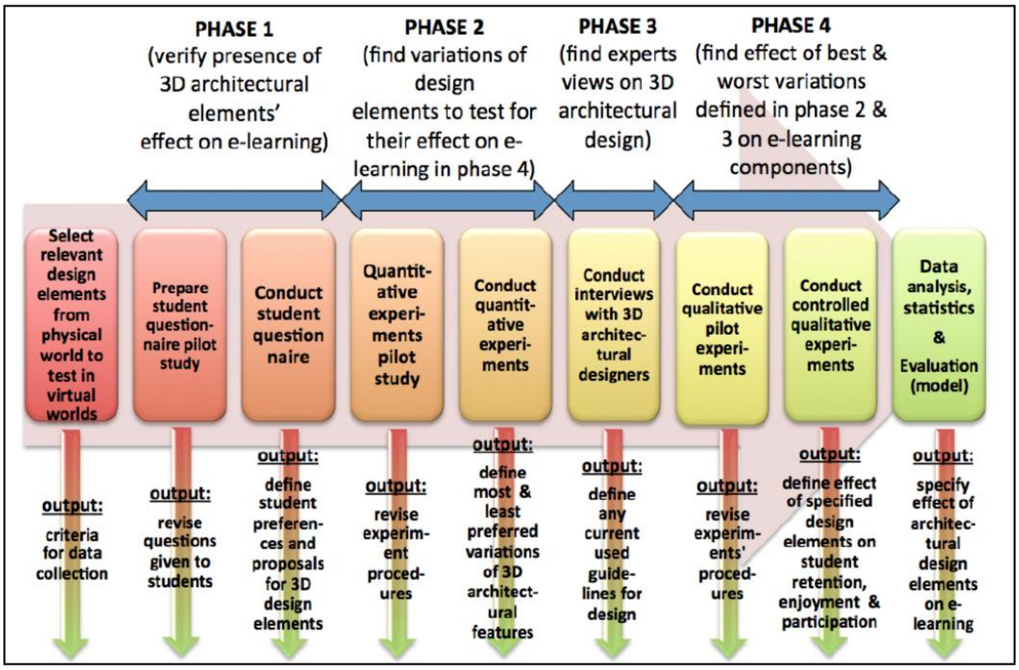

Figure 1. Sequential research stages to prepare a working list of 3D architectural design elements for 3D virtual educational facilities to enhance the e-learning process

A summary of the approach is illustrated in the figure below that clarifies how each phase consists of a number of steps and their associated outputs. Each output has a specific objective that must be mapped to specific research objectives, while the identified steps compose the overall research process of the study.

As shown in figure 1, the four data collection phases can be identified as follows:

I. Verifying the impact and specific effects of 3D architectural elements on e-learning.
II. Identifying variations of design elements for testing with respect to different effects on e-learning.
III. Obtaining expert views on 3D architectural design.
IV. Findings the effect of best and worst variations from design elements on e-learning components.

Many participants within the experiments, in this phase of data collection, took part earlier in phase 1 surveys and phase 2 quantitative experiments. The total number of students who consented to participate was 77, from the School of Engineering at Middlesex University, distributed almost evenly among 6 groups (classes) from different year levels – foundation and final year.

The steps associated with each phase are as follows:

I. Architectural element impact
   a. Collection of design elements, focusing on selecting relevant design elements from physical world to test in virtual worlds (associated output: criteria for data collection).
   b. Design of primary data collection tools focusing on preparing student questionnaires for pilot studies (associated output: revised questions for student participants)
   c. Conduct data collection focusing on conducting student surveys (associated output: definition of student preferences and proposals for 3D design elements)

II. Design element variations
   a. Design pilot study for quantitative data collection focusing on designing quantitative experiments pilot study (associated output: revised experiment procedures)
   b. Conduct quantitative experiments focusing on experiment stages and data collection (associated output: definition of the most and least preferred variations of 3D architectural features)

III. Expert views
   a. Design interview-based data collection focusing on conducting interviews with 3D architectural designers (associated output: definition of currently used design guidelines for 3D spaces)
   b. Conduct semi-structured interviews focusing on obtaining expert views (associated output: collection of architectural features used in 3D spaces)

IV. Effect of element variations
   a. Design pilot study for quantitative data collection focusing on preparing the necessary data collection tools (associated output: experiment guidelines and pilot scenarios)
   b. Conduct qualitative experiments focusing on (associated output: revised experiment procedures)
   c. Perform statistical data analysis focusing on (associated output: definitions of the effects from each design element on student retention, enjoyment and participation)
   d. Evaluate proposed conceptual model focusing on reflecting on aspects of each architectural feature and its impact on e-learning (associated output: revised conceptual model and framework for good practices)

4. PROPOSING BEST DESIGN PRACTICES FOR 3D VIRTUAL LEARNING SPACES

The results of the data collection process in this research study are summarized in a series of three tables. Due to the page limitations only one of these tables is included in this paper. The data collection results were analysed using inferential statistics tests ANOVA and CHI^2 to prove their representation of the whole population of higher education students in 3D VLEs. Included in the tables is also a set of guidelines to help initialize a framework for architectural design of 3D educational facilities in 3DVLEs analogous to that existing in the physical world. For each row in the table representing an architectural design element, the findings are divided up into 5 sections denoting the 5 columns in the tables as follows.

- Best design recommendations for that architectural element used in real-life to build physical learning spaces – derived from literature review.
- 3D virtual design elements favoured by students (under-graduate, post-graduate and adult learners) for an e-learning space in 3D VLEs – derived from phase 1 questionnaires.
- Specific variations of the design element that are best preferred by students (males and females) for their 3D virtual learning space – derived from phase 2 experiments.
- Best design guidelines provided by designers for each architectural element – derived from phase 3 interviews.
- The variation of each design element inducing most retention, participation and enjoyment from students – derived from phase 4 experiments.

The findings of the 5th column in the tables are the only ones, which can be included in an initial framework of guidelines for designing educational spaces in 3D VLEs. This is because their specific effects on retention, participation and enjoyment of students during e-learning have been tested, measured and validated, unlike other recommendations in the other columns which have not all been tested and thus can only be considered tentatively for designing in 3D VLEs until further tested in future work.

The colour codes used in the table are representing the following:

- Green denotes all design recommendations for virtual buildings (from phases 1-4 / columns 2-5) that are **similar** to design guidelines for real-life buildings (column 1).
- Red denotes all design recommendations for virtual buildings (from phases 1-4 / columns 2-5) that are **different** from design guidelines for real-life buildings (column 1).
- Yellow denotes all design recommendations for virtual buildings (from phases 1-4 / columns 2-5) that are **contradicting** with all other columns including contradictions inside the same column.

As evident from the table, the only architectural element where the best design recommendations for building 3D virtual learning spaces were the same as those for building physical learning spaces was colour. All other 3D virtual design recommendations for all other architectural elements, whether tested in phase 4 or just preferences of students, were different from those used in real-life. This provides evidence for the research argument, mentioned in chapter 1, that best design specifications for building 3D virtual educational facilities might be different from those in the physical world due to the disparity in nature between both environments. This therefore emphasizes the significance of this research to derive the new design specifications best suited for students' e-learning in 3D VLEs. Furthermore this fact highlights the ad-hoc practices of current virtual designers who either use real life design guidelines based on their experience to build in 3D VLEs, or other untested virtual design guidelines based on their personal tastes not on students'.

Shape

Regarding the shape of the learning space, best recommended in real-life is the rectangular shape or L-shape. According to Rensselaer (2010), this is because a rectangle with width more than half and less than two-thirds the length is much more pleasing than a shape with no comparative dimensions - the shape would be obvious at once, nothing is left to the imagination. Also the L-shape is multi functional and provides less variation of decay rate of sound than the rectangle (Sato and Koyasu, 1959). However table 2 demonstrates that preferences of students (from phases 1 and 2), and tests (from phase 4) reveal that the circular shape induces higher retention, participation and enjoyment during e-learning in 3D VLEs than the rectangular shape of the same size (but similar to a rectangle with double the size of the circle). This could be because as Batson (2010) claims, rooms should be rounded since sight lines and visual perception of space is relatively easy with equal dimension shapes. Also the circle gives a sense of connection, community, wholeness, safety, perfection, and comfort (which students agreed on in phase 2 experiments), while rectangles are associated with order, logic, and containment. While rectangles also suggest mass and volume in real-life because of their rigid points, the perception is possibly different in 3D VLEs, since as told by students during phase 2 and 4 experiments in Second Life, the circle room was perceived as bigger even though it was the same area as the rectangle room also tested. Interviews with designers showed contradictory opinions between commending rectangular, circular and octagonal shapes, proving the ad-hoc, currently undefined process of 3D virtual design, which is not based on students' needs. Conclusively, usage of circular shapes for e-learning spaces in 3D VLEs can be added to the framework of design guidelines for 3D virtual educational buildings.

Table 1. General Results and an initial framework of architectural design recommendations for Building in 3D VLEs (shape / size / interior lighting & open walls / colours / textures)

Architectural Design Guidelines Recommended for Building Educational Facilities in Real Life, and 3D VLEs					
	Most recommended in Real Life Design of Educational Facilities **(Literature)**	Virtual Design Elements in 3D VLEs from the 4 Phases of Data Collection & Analysis			
		Most preferred by students **(Phase 1)**	Most preferred by students **(Phase 2)**	Most recommended by designers **(Phase3)**	Most enhancing Retention, Participation, Enjoyment **(Phase 4)**
Space Shape	**L-shaped, Rectangle width:length = 1:2**	under graduate: **circle** post graduate: **rectangle** adult learner: **circle**	males: **circle** females: **circle**	**- rectangle / cube shape** **- circular or octagon shape**	**Circle**
Size Dimensions & Height	**Area ~ 30m sq. length : width = 2:1 minimum width 4m**	under graduate: **large, width:height = 4:1** post graduate: **large, width:length:height = 1:2:1** adult learner: **large, width:height = 4:1**	males: **large width, height, length than real-life** females: **large width, height, length than real-life**	**- size 200% > real-life** **- size 150% > real-life** **- size 25% > real-life** **- maximum length 40m** **- maximum length 20m** **- minimum length 15m** **- minimum length 10m** **- no minimum length** **- minimum height 5m**	**Area (~ 250m sq. = 8 times size of class in real-life) Height - 7m**
Interior Lighting & Open Walls %	**20% open walls for windows**	under graduate: **50% open walls/roof, strong internal lighting** post graduate: **60% open walls/roof** adult learner: **50% open walls/roof**	not tested	**- 50% open space** **- 100% open space** **- define completely open spaces with borders e.g. trees, pillars** **- phantom (walk-through) walls** **- walls transparent on approach**	**60% open walls and ceiling**
Colours	**Light colours e.g. white, green, blue**	under graduate: **light bright colors, paneling above windows** post graduate: **light bright colors, paneling above windows** adult learner: **light bright colors**	males: **green, grey, white, light blue** females: **white, green, pink, light blue**	**- no overcolouring** **- soft cool neutral pastel colours** **- colours not too bright or warm (except for children)** **- no solid black or white**	**Light blue**
Textures / Floor, Wall & Ceiling Design	**Tiles, wood for floors. Stucco for walls. Stucco, artificial panels for false ceiling**	under graduate: **mixed color wood , dark smooth carpeting** post graduate: **smooth carpet flooring, rough outdoor tiles, retractable glass roof** adult learner: **light wood, open roof, no dark textures**	males: **light wood, metallic, carpet / stained glass & glass / decorative, arabian, coloured panels** females: **light wood, vinyl carpet / stained glass & glass / arabian**	**- no over texturing or patterns** **- plain textures e.g. stone wood concrete stucco marble tiles** **- no glow or interlacing** **- no carpet , brick, plywood (SL default)** **- use high quality texture** **- use sky, nature texture** **- grey industrial feel** **- corroded faded effect** **- glass walls** **- dome roof, semi-open or open**	**Light wood, glass & stained glass, coloured panels**

virtual design guidelines from the 4 phases SIMILAR to physical design guidelines in real-life (green)

virtual design guidelines from the 4 phases SIMILAR to each other, NOT SIMILAR to physical design guidelines in real-life (pink)

contradictory virtual design guidelines from the 4 phases NOT SIMILAR to each other or physical design guidelines in real-life (yellow)

Size

The association between class size and student achievement has been investigated in the past (Ehrenberg et al, 2001). According to Hall (2001) the optimum number of students in a physical classroom is 15 to give maximum benefit for learning achievement. Hence all physical and virtual learning space sizes considered in this thesis are for 15 students. In real-life, a common classroom size for such a number is 30m2 with ceiling height 3-4m, although Eberhard (2008) recommends a minimum area of 60m2, and an optimum area of 80m2 to allow adequate movement between students. In Second Life, during phase 4 experiments, this area was found to be too small for students' comfort and preference. As demonstrated in table 2, the area of a 3D virtual class or seminar room encouraging highest retention, participation and enjoyment in 3D VLEs was 240m2 with a ceiling height of 7m for a 15-student group. This is 8 times the size of a normal physical classroom, and 3 times the size of an optimum physical area. This contradicting finding to real-life was encouraged by students' preferences from phase 1 and 2, and tested in phase 4. A much larger 3D virtual size of 500m2 also induced high enjoyment but with a decrease in retention and participation. Similar to the previous design element, designers' opinions from interviews of phase 3 were contradictory with each other regarding minimum and maximum lengths, widths and heights, as shown in table 2. This provides further evidence to the indeterminate current process of 3D virtual design. Conclusively, recommending usage of 240m2 area and 7m height for e-learning spaces in 3D VLEs can be added to the framework of design guidelines for 3D virtual educational buildings.

Interior Lighting and Percentage of Open Walls

According to Fink (2002), The use of natural lighting with manmade lighting is believed to be positive for learning in real-life. Exposure to full-spectrum lighting is associated with better attendance, more positive moods, great concentration, and better scholastic performance. Thus it could be inferred that more exposure to light might improve the students' learning process. In physical classrooms, the percentage of open walls dedicated for windows is ~ 20%. According to students' preferences (in phase 1), and based on phase 4 experiments, 60% open walls and ceilings induced highest retention, participation and enjoyment, which is contradictory with real-life design guidelines. Again here designers' opinions were contradictory with each other and the tested findings indicating the designers' non-compliance with students' needs and requirements. Using 60% open walls and ceilings can therefore be recommended for the framework of design specifications for 3D virtual educational buildings.

Colours

Fink (2002) suggested soft colours in classrooms were associated with better attendance and positive attitudes in real-life. Also while warm colours can visually reduce space scale and size, cool colours visually enlarge a space making it less confining (Daggett et al., 2008). Specifically, lighter shades of green and blue, like nature, induce positive relaxation and comfort emotions, helping create a calm learning atmosphere, filter negativity and reduce disciplinary problems (Sasson, 2007). Also no more than 6 colours should be used in a learning environment as this could strain the mind's cognitive abilities, cause eyestrain, glare and distraction. As shown in table 2 there was an agreement regarding best favoured colours to use inside a learning environment in both physical and virtual class rooms. For while white, blue and green (cool colours) are most prominently used in real-life, light blue was found in phase 4 experiments to induce higher retention, participation and enjoyment for students than the other tested colour (yellow). Furthermore blue received highest regard by students in phase 1 and 2, and also by designers in phase 3 interviews, along with recommendation for soft colours and no over colouring of the virtual environment. Thus using light blue colour can be recommended for the framework of design specifications for 3D virtual educational buildings.

Textures

According to Interrante & Kim (2001), highly anisotropic textures in real-life can hinder perception of shape, i.e. if they consist of elements that are elongated in a specific direction. Commonly used textures in real-life are tiles and wood for floors, stucco and tiles for walls, stucco and artificial panels for ceilings. These are contrary to findings for the optimum textures to be used in 3D virtual spaces, as derived from phase 4 experiments and approved by students in phase 1 and 2. The 3D textures inducing highest retention, participation and enjoyment for floors, walls and ceilings were lightwood, glass and stained glass, and coloured panels. The only agreement with real-life textures was that all should be plain as indicated by Interrante & Kim (2001). Designers suggested completely contradicting textures between grey, rough, brick and others, which are completely different from students' needs and desires. Thus using lightwood, glass and coloured panel textures can be recommended for the framework of design specifications for 3D virtual educational buildings.

Table 2. General Results and an initial framework of architectural design recommendations for Building in 3D VLEs (architecture style / window design / seating arrangement / building entrance)

Architectural Design Guidelines Recommended for Building Educational Facilities in Real Life, and 3D VLEs					
	Most recommended in Real Life Design of Educational Facilities **(Literature)**	Virtual Design Elements in 3D VLEs from the 4 Phases of Data Collection & Analysis			
		Most preferred by students **(Phase 1)**	Most preferred by students **(Phase 2)**	Most recommended by designers **(Phase3)**	Most enhancing Retention, Participation, Enjoyment **(Phase 4)**
Architecture Style	not researched	under graduate: **modern style** post graduate: **classical & modern** adult learner: **modern style**	not tested	**- realistic, modern style** **- realistic classical style** **- imaginative design style** **- use themes from real campus** **- avoid too many details** **- consistency in design theme**	not tested
Window Design	**Palladian, bay windows**	under graduate: **bow windows** post graduate: **arched windows** adult learner: **bow windows**	not tested	**- use arches in line** **- use split walls, half partition half open or window** **- use semi-transparent glass walls** **- no walls, all glass** **- no windows**	not tested
Seating Arrangement	**Linear rows or grouped seats and desks**	under graduate: **semi circular & circular rows** post graduate: **semi circular seating, leisurely (pool) seating** adult learner: **semi circular, circular and open rows**	not tested	**- circular / non-linear rows** **- linea r rows** **- large space between rows - 2m** **- no desks** **- minimum personal conversation distance 1.5m**	not tested
Building Entrance	**Accentuated entrance**	under graduate: **wide entrance** post graduate: **easily accessible entrances** adult learner: **wide entrances, few stair steps per flight**	not tested	**- wide simple pronounced entrance** **- no doors or no closed doors** **- 2.5m x 2m door opening** **- avoid detailed or prim extensive doors** **- use reflections on glass doors** **- use teleports**	not tested

virtual design guidelines from the 4 phases SIMILAR to physical design guidelines in real-life (green)

virtual design guidelines from the 4 phases SIMILAR to each other, NOT SIMILAR to physical design guidelines in real-life (pink)

contradictory virtual design guidelines from the 4 phases NOT SIMILAR to each other or physical design guidelines in real-life (yellow)

Other Architectural Design Elements

The other design elements represented in table 2 were not chosen for testing and verification in phase 2 and 4 experiments since they have not been researched in real-life for their effects on learning and do not exist inside the 3D virtual learning space. Thus their results should not be included in the framework of design specifications for 3D virtual educational buildings. However the results still show that, even though untested and unverified, student preferences from these elements for the design of the 3D virtual environment are different from those used in real-life. They also show that designers' propositions are contradictory with those required by students and those used in real-life, displaying the designers' experience e.g. virtual ramp slopes to be 4:1 as opposed to 6:1 in real-life, virtual stair step height to be 30cm as opposed to 17 cm in real-life. These design elements include architectural style, window design, seating arrangement, corridors, entrances, site-planning, and terrain. These recommendations can be taken into consideration for future research as explained in the next section.

5. CONTRIBUTION TO KNOWLEDGE

The main contribution to knowledge within this research is providing evidence that 3D virtual architecture affects e-learning in 3D VLEs. However, this research study offers the following four (4) contribution outcomes to the body of knowledge. Each contribution complements all three (3) major fields addressed in this study, namely (i) education, (ii) architecture, and (iii) information and communication technology (ICT) as follows:

- By synthesising and defining advantageous and disadvantageous themes of using 3D Virtual Learning Environments. This contribution allows future researchers to determine how 3D VLEs can be used for enhancing learning and support learners in various activities.
- By producing evaluation and assessment reports of the effects of 3D virtual educational architecture on student satisfaction from e-learning in 3D Virtual Learning Environments to fill in the gap of research in this area. This was attained through analysis of the data results collected from the questionnaires of phase 1 and experiments of phase 2 during the process of this research.
- By deriving 3D virtual design elements of learning spaces best suited to enhance students' e-learning experiences, namely retention, participation and enjoyment. This was attained through analysis of the data results collected from phase 4 experiments during the process of this research. This contribution is essential for organizing the otherwise ad-hoc current 3D user specifications used for building educational facilities in 3D Virtual Learning Environments unveiled by designers in phase 3 interviews.
- By creating an initial framework of design guidelines or specifications for modelling successful learning spaces in 3D Virtual Learning Environments, which is currently non-present, to be comparable to its counterpart used for building in the physical world. This was achieved through analysis of the data results collected from phase 4 experiments

The first contribution is theoretically beneficial for educators considering incorporating 3D virtual Learning environments in their programs and weighing the advantages against disadvantages of utilising them for teaching students. The second, third and fourth contributions are practically beneficial for practitioners in the field, namely designers and experts building inside 3D VLEs, to utilize the issued tested recommendations and findings in this thesis to create future 3D virtual educational buildings and campuses inside 3D VLEs for best enhancement of the e-learning experience. This is because in agreement with Smelik et al. (2010), one of the main challenges ahead is to enhance the level of control provided to designers, who will often wish to manually edit and fine-tune built entities on a more detailed level than just terrain features in a virtual world, to more precisely fit their requirements. The work done in this research helps customisation and enhancement of the 3D learning space by (i) providing definite preferences and dislikes towards certain variations of architectural design elements, and proposed suggestions offered by students for improvement of their learning space design and (ii) providing specific variations of 3D architectural elements to enhance measured retention, participation and enjoyment of students.

6. CONCLUSION

Our research was based on two key arguments. Our first argument was that it is plausible to consider that architectural elements of 3D virtual educational buildings might have an impact on students' e-learning enhancement analogous to that of physical architectural elements of learning spaces on physical learning. Both our extensive literature review that has been recently been revised and the findings from our multi-stage data collection advocate our research argument. Our second argument is that it is plausible to investigate and define design specifications and optimum guidelines for building 3D virtual educational facilities to enhance the students' e-learning experiences in 3D VLEs. It is probable to expect these specifications to be different from those in the physical world due to the fundamental disparity between both environments explained earlier. Our set of guidelines has been tested in the final parts of our research by introducing enhanced learning spaces in 3D virtual worlds leading to improved learning experiences, student satisfaction and assessment results.

This paper presented a multi-stage method for primary data collection in virtual worlds, with emphasis on the 3D VLE elements and their impact on e-learning. The paper emphasized on the importance of each stage for collecting user perceptions and monitoring user behavior in learning scenarios. The method also covers primary data collection tasks associated with the collection of expert views, as well as offering data collection triangulation and validation. The proposed method provides a good practice framework for similar studies but also any scenario-based research pilots involving 3D VLEs or virtual worlds in general. The paper also provides a summary of findings for key architectural elements with proven impact on learning processes supported with 3D VLEs.

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