

THE ROLE OF ARCHITECTURAL DESIGN IN VIRTUAL WORLDS FOR EDUCATIONAL PURPOSES

Noha Saleeb, Georgios Dafoulas and Martin Loomes
*Computer Science Department, School of Science & Technology
Middlesex University*

ABSTRACT

This paper discusses the investigation of how architectural digital design elements of virtual worlds affect learning experiences. 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. 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.

KEYWORDS

Virtual Worlds, Second Life, 3D Virtual Learning Environments, architectural design

1. INTRODUCTION

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.

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.

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).

2. 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.

2.1 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 **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 **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 **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 pre-designed 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.

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.

2.2 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.

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.

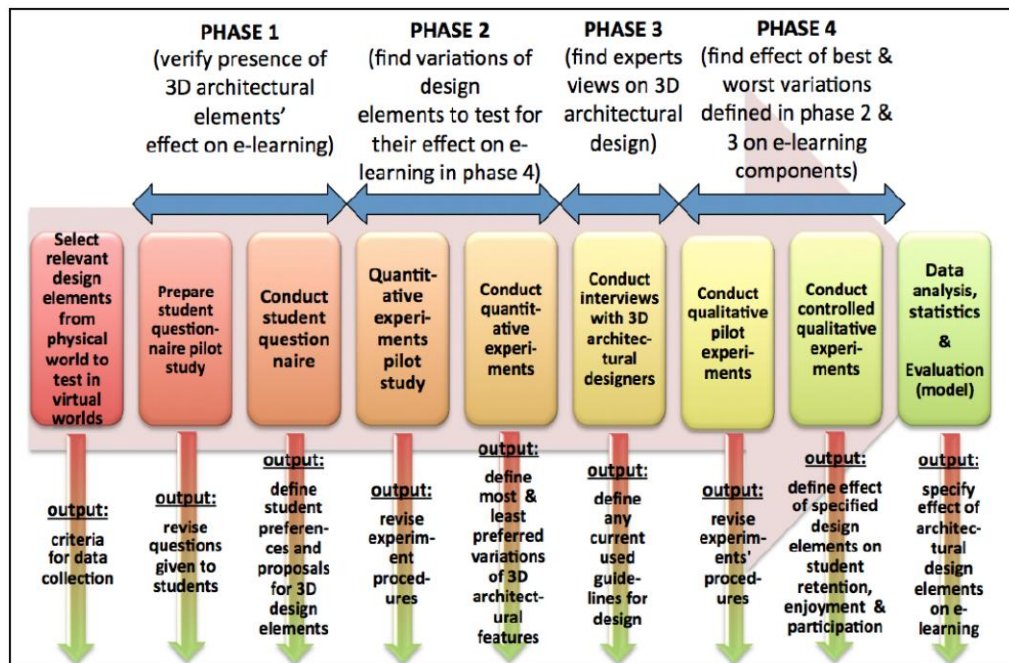


Figure 1. Sequential research stages to prepare a working list of 3D architectural design elements for 3D virtual educational facilities to enhance the e-learning process

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)

3. 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'.

Table 1. General Results and an initial framework of architectural design recommendations for Building in 3D VLEs

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 (Phase 3)	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

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.

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.

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.

4. 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.

5. CONCLUSION

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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