Closing the Chasm between Virtual and Physical Delivery for Innovative Learning Spaces using Learning Analytics

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Abstract

Purpose

One of the misconceptions of teaching and learning for practical-based programmes, such as engineering, sciences, architecture, design and arts, is the necessity to deliver via face-to-face physical modality. This paper refutes this claim by providing case studies of best practices in delivering such courses and their hands-on skillsets using completely online virtual delivery that utilises different formats of 2D and 3D media and tools, supported by evidence of efficiency using learning analytics.

Design/methodology/approach

The case studies were designed using pedagogical principles of constructivism and deep learning, conducted within a mixture of 2D and 3D virtual learning environments with flexible interface and tools capabilities. State-of-the-art coding and scripting techniques were also used to automate different student tasks and increase engagement. Regression and Descriptive Analysis methods were used for Learning Analytics.

Findings

Learning analytics, of all case studies, demonstrated the capability to achieve course/project learning outcomes, with high engagement from students amongst peers and with tutors. Furthermore, the diverse virtual learning tools used, allowed students to display creativity and innovation efficiently analogous to physical learning.

Originality

The synthesis of utilised media and virtual tools within this study displays innovation and originality in combining different technology techniques to achieve an effectual learning experience. That would usually necessitate face-to-face, hands-on physical contact to perform practical tasks and receive feedback on them. Furthermore, this paper provides suggestions for future research using more advanced technologies.

Keywords

Educational collaboration platforms, 3D Virtual learning environments, learning analytics, online learning spaces, deep learning methods, constructivism, effectual learning experience, audio video communication, application integration, distance learning, innovative teaching techniques, artificial intelligence pedagogy tools, learning management system, descriptive analysis, regression

Article Classification

Case Study

Introduction

"**Learning analytics** is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (Drachsler et al., 2012). It has been well established over the last decade that Learning Analytics can be utilised to resolve many challenges that face current educational institutions (Haythornthwaite et al., 2013). Such challenges include non-engagement of students, poor performance on academic, scientific and innovative activities, student diversity and even insufficient resourcing and funding etc. (Ognjanovic et al., 2016). Furthermore, are numerous reasons that could necessitate using virtual approaches for delivering teaching and learning in higher educational institutions as described below. This paper discusses a multitude of innovative online virtual methods, used to deliver both undergraduate and postgraduate programmes, that in tandum with Learning Analytics applied upon their implementation displayed achieving an equally successful experience as physical delivery, as recorded by the performed Learning Analytics. Reasons for adopting this mode of online pedagogy were:

1. Delivering work-based learning and courses to remote professionals globally while in the workplace, who cannot physically attend at university.
2. Delivery of practical courses and modules remotely which normally require face-to-face delivery, such as science, technology, engineering, architecture courses. This allowed students to study these practical-based courses remotely, hence increasing student numbers, and also in case of non-ability to attend in person or in case of emergency (e.g. recent global lockdown due to health crisis).
3. Producing coursework and performing group collaboration with remote teams online, e.g. in cross-disciplinary projects or among different organisations / universities.

Upon identification of the necessity to adopt online virtual methods for teaching and learning, it was necessary to identify 3 essential factors:

1. Suitable online media with appropriate tools for delivery
2. Pedagogical criteria needed to satisfy within this mode of delivery, that would allow achieving the programmes' learning outcomes, as well as a successful and enjoyable learning experience analogous to face-to-face delivery.
3. Learning Analytics methods to measure engagement and achievement/performance of students as a result of utilising these online virtual methods

This paper is part of a research, the goal of which is to utilise Learning Analytics and Online Virtual Techniques to deliver a more engaging and productive educational experience for students. The novelty and contribution of this paper lies in presenting customised efficient teaching/learning techniques to achieve this goal utilising effective pedagogical theories.

The next sections identify the pedagogical theories adopted underlying the online virtual teaching techniques used, followed by the Learning Analytics methods implemented for measuring student engagement / performance, then case studies of how this was put into practice and media utilised for online teaching and learning.

Pedagogical Background

Deep Approach to Learning

There are two identified approaches to learning, deep and surface. As evident from the characteristics in Figure_1, with surface approach to learning, students use tactics like memorisation to accomplish their academic tasks and are therefore "focused on reproducing" knowledge. However deep learning is "focused on understanding" content for own development and interest (Oxford, 2017); interacting strongly with information/materials using prior "knowledge and experience". This involves engagement with analytical cognitive functions, evaluation and synthesis for in-depth attainment of knowledge, thus achieving "higher quality learning outcomes" (Li & Wong, 2019).

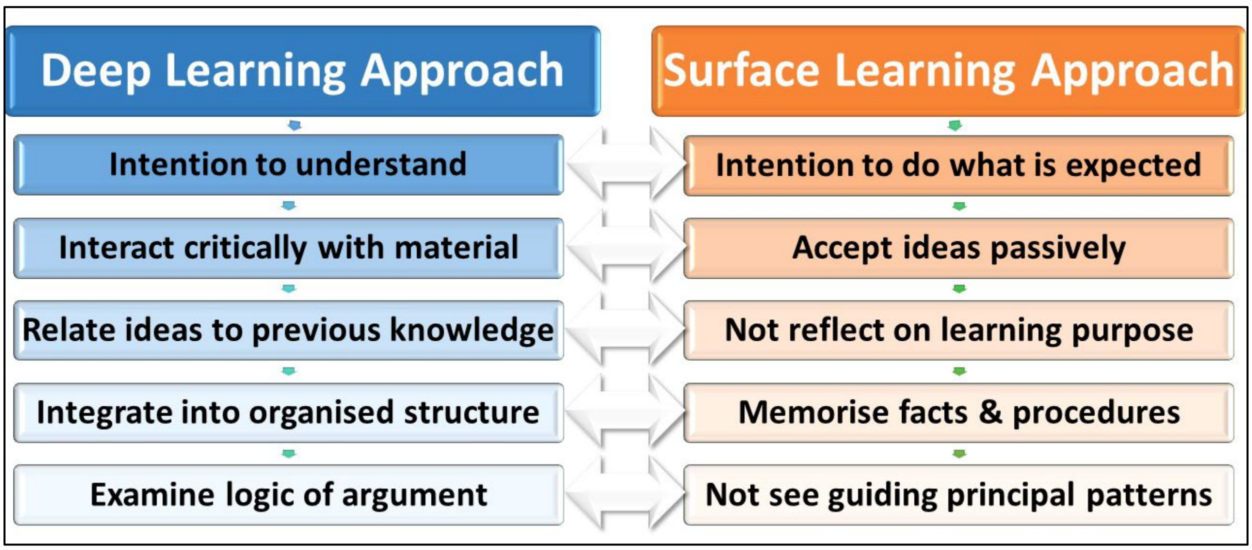

Figure_1: Characteristics of Approaches to Learning

Teaching techniques should hence create an active, learner-focused environment. Wang (2013) proposes "good teaching", "clear goals and standards", suitable "assessments", encouragement towards autonomous "learning" and quality feedback to adopt deep-learning strategies. Many students however adopt deep-learning strategies while adopting the surface-learning strategy to complete assessments/pass (short-term goals), since certain assessments might require memorisation of facts and regurgitation of specific details (Desierto et al., 2018).

Regression analysis in experiments conducted by Li & Wong (2019) demonstrated that deep-learning was a significant predictor of metacognition levels (awareness and understanding of one's own thought processes). Furthermore, project-based learning (PBL) experiments conducted by

Dolmans et al. (2016) showed boosting deep-learning through active and self-directed learning, with analysis, compare/contrast and evidence hypotheses.

This approach to PBL was adopted within the case studies described subsequently, conducted in both 2D and 3D virtual learning environments (VLEs), to encourage deep and self-directed approaches, encouraging students take responsibility/ownership over their own learning through freedom to select own resources.

Effectual Virtual Learning Experience

Virtual learning environments can either have 2D interfaces, e.g. Adobe Connect, Zoom, Kaltura, Teams, GotoWebinar, or provide a 3D immersive environment e.g. Second Life, OpenSim. As the uses of 2D and 3D virtual environments/spaces alternated between entertainment, business, education etc., it was imperative to analyse how these spaces function, and which have best options to offer for education (Squire, 2002). Through analysis of many virtual environments, a list of technical characteristics were first identified that influence choosing the media that can provide highest quality of educational experience possible in a virtual space (Robbins, 2007):

1. Maximum number of users able to login simultaneously without crashing the system
2. Dominant content form of the environment: i.e. text, audio/video, 2D image, 3D object/avatar etc.
3. Persistence of Environment: existing when user is not logged in keeping changes/objects/logs/documents in the environment
4. Stigmergy: allowing users to leave messages, objects and other forms of communication for others to find when they login later.
5. Collaborative/immersive User's relationship with other users and environment

Furthermore, based on discussions by Calongne (2008) depicting experiences of university staff in the delivery of courses using 3DVLEs as an educational classroom, and own experiences, Figure 2 below was generated illustrating a blend of derived characteristics required for successful and effectual virtual class experiences.

***Technology**:* refers to all software, add-ons, networks, cloud services, hardware peripherals (e.g. for sketching, scanning, analysing, haptics, remote access, AI capabilities that can be utilised within the virtual learning environment.

Tools: for delivery, monitoring, quizzes, assessment, sharing content, audio/video etc.

Content delivery: ability to deliver structured syllabus, tutorials, flipped classroom using presentations, project work, creations, activities, forums etc.

Student Ownership: student personalised possession of created and acquired objects and gadgets inside the virtual environment/world, and sense of belonging to a private secure space not general to all.

Self-Identity: through desire to customise own account/avatar’s appearance at the beginning or during sessions.

Engaging Interaction: discussions, polls, debates, collaborative work e.g. using treasure hunt group work technique to find forensic evidence or create models.

Navigation/Exploration: in 3DVLEs teleportation/movement/flying from one space to another

Risk Management: alternative mitigation solutions for failure of one mode of delivery e.g. different file format presentations, activities, whiteboard etc.

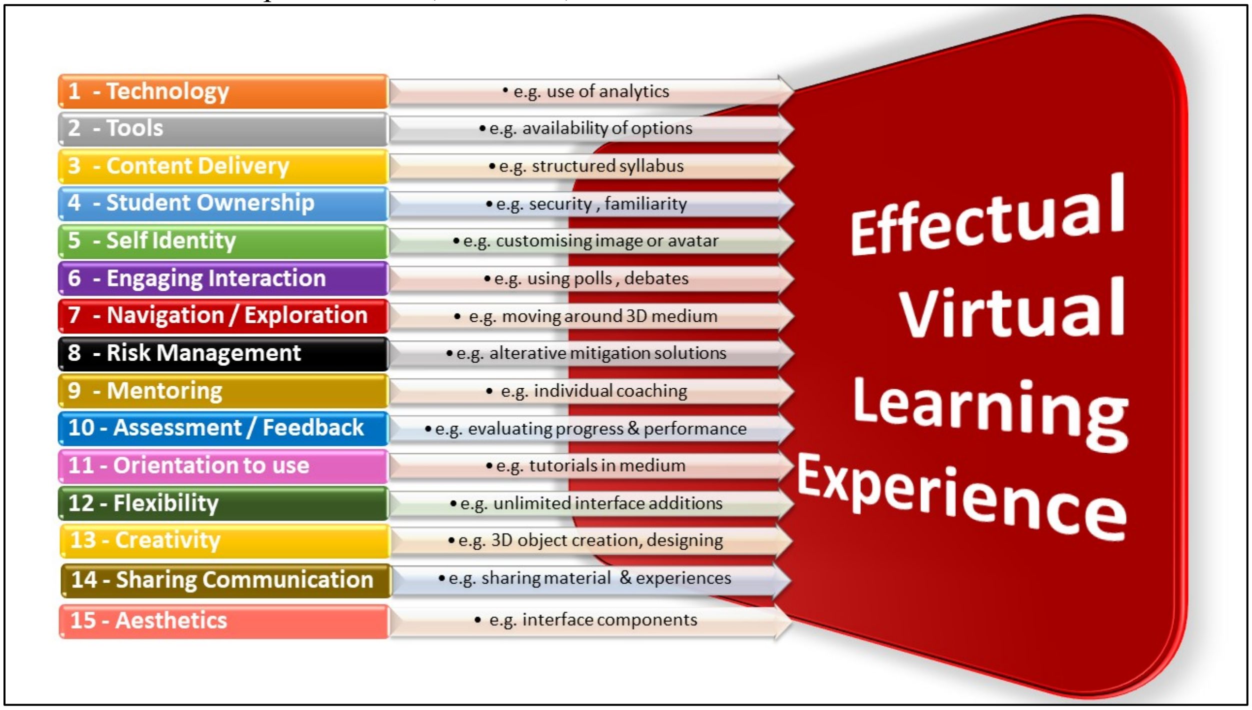

Figure_2: Characteristics required for an Effectual Virtual Learning Experience

Mentoring: having one-on-one sessions with students, providing mark-up annotations live online

Assessment/feedback: providing prompt guidance online through messaging, audio/video response, feedback links, or for 3DVLEs leaving comments inside "in-world note-cards" obtained from 3D objects inside a user's online inventory. Available analytics to monitor attendance and performance statistics

Orientation: how to navigate, use options and building tools etc. provided by the virtual space

Flexibility: ability to change the interface of the medium, adding different sized multi-function windows and tools

Creativity: building objects defying laws of physics, buying/attaching "inworld" gadgets to avatars

Sharing/Communication: Conversations, saving chat logs, sharing files, objects etc.

Aesthetics: ability to customise interface, to enhance appearance of medium

These characteristics were taken into consideration during choice of appropriate media for delivering virtual teaching and learning. The ones selected that would achieve the above were Adobe Connect (2DVLE), and Second Life (3DVLE) as explained in the subsequent case studies. These characteristics were perceived to achieve an effectual (capable of achieving outcomes) virtual learning experience in the following two advantageous themes for using Virtual Learning Environments as an educational tool:

1. Proving that VLEs enhance and complement traditional methods of physical learning (points: 3-content delivery, 6-interaction, 8-risk management, 9-mentoring, 10-assessment/feedback, 13-creativity, 14-communication)
2. Proving that VLEs not only support conventional methods of learning but also present e-learning opportunities that are not possible to attain using physical methods (points: 1-technology, 2-tools, 4-ownership, 5-self-identity, 7-navigation/exploration, 11-orientation, 12-flexibility, 15-aesthetics)

Constructivism

Construction of knowledge is a dynamic procedure requiring active engagement of learners responsible for their own learning via self-created activities to understand own experiences; while teachers are facilitators - only create an effective learning environment and curriculum for self-directed student learning. Hence constructivism requires 1) experience (personalised experience-based learning), 2) adaptation (accommodation to learner's individuality) (Huo, 2019), 3) dependency on individual/collective understandings, backgrounds, and tendencies (Anderson, 2016).

Mattar (2018) necessitates inclusion of the following for constructivism: 1_Situated Cognition (importance of context and interaction in knowledge construction), 2_activity theory (importance of learner engagement and action to support learning), 3_experiential learning (importance of experience in constructing knowledge), 4_anchored instruction (recalled knowledge when people are explicitly asked anchored instructions), and 5_authentic learning (have real-world relevance). All of which are included in the case studies describes subsequently.

Tam (2000) connects constructivism, technology supported learning environments and distance-education. Distance-learning provides a unique context where learners function as self-motivated, self-directed, interactive, and collaborative participants in their learning experiences. The previous theories support adopting the constructivist paradigm/approach to teaching and learning in the case studies described in this study. As indicated by Mikropoulos and Natsis (2011), Constructivism seems to be the theoretical model most 3DVLEs are based on. Explained further by Dalgarno and Lee's (2010) conception that "technologies themselves do not directly cause learning to occur but can afford certain tasks that themselves may result in learning", locating problems, assisting to accomplish tasks and improving the cognitive powers of students (Makewa, 2019).

Thus, examples of supporting the constructivist paradigm will be seen in the following case-studies that fulfil the seven principles of constructivism as presented by Jonassen (1994), depicted in Figure 3 below, with examples of tools to achieve them assembled by the author.

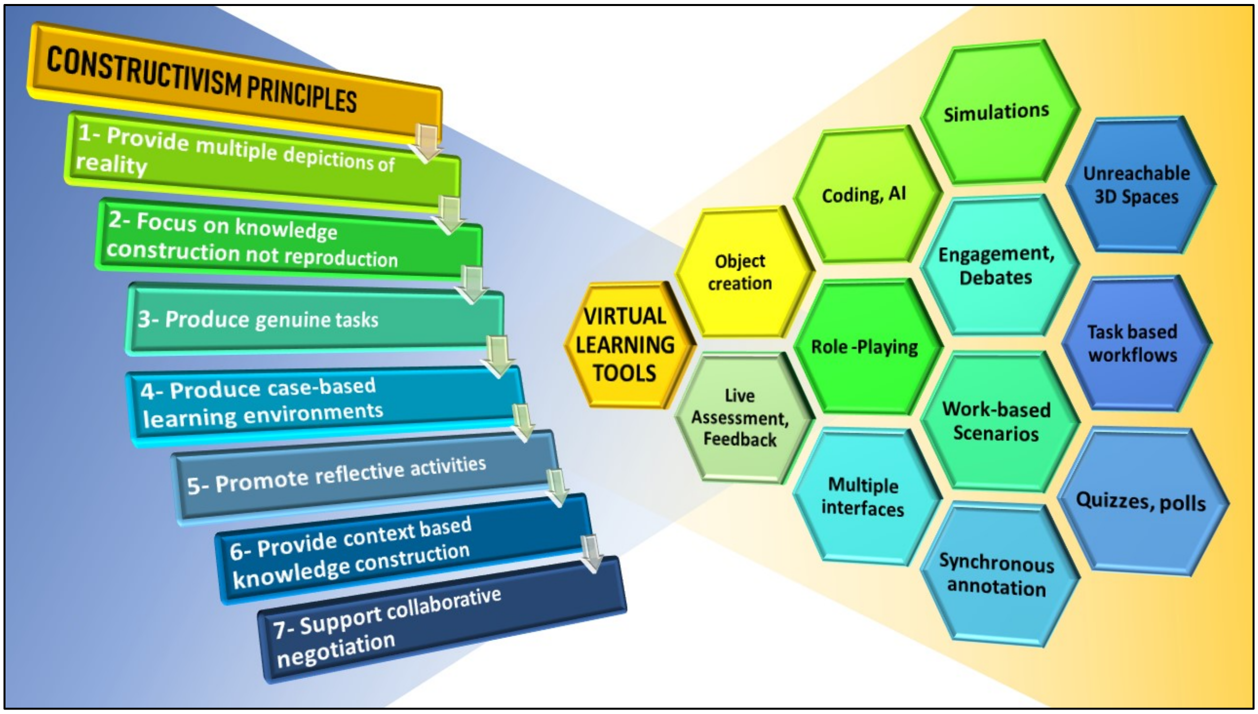

Figure_3: Principles and Tools for Constructivism

The curriculum could encompass programming, simulations, and coding bots (artificial intelligence automated avatars) inside 3DVLEs to offer interactive activities for students. This is in addition to role-playing different scenarios in 2D or 3D media, creating 3D objects, assets, modelling and visiting unreachable sites in 3D. Since students have diverse perspectives, backgrounds, learning styles and experiences, this collaborative learning environment would provide different constructivist experiences (Ham and Schnabel, 2011).
The next section will demonstrate several educational scenarios through the creation and use of bots (artificial intelligence automated avatars) inside Second Life, an example of 3D Virtual Learning Environments, to create different interactive projects and activities to enhance students' e-learning.

Methodology

Learning Analytics

As per Avella et al. (2016) and Viberg et al. (2018), there are numerous methods to implement Learning Analytics within educational programmes. The following methods were used: *Prediction* – e.g. of student performance and engagement in future. This method was utilised in this study at the culmination of a full term of data collection from 5 different classes of students (3 undergraduate classes of 45 students / 2 post graduate classes of 40 students) who received the different online virtual learning techniques described in the subsequent section. Descriptive analysis was used by creating Linear Regression Scatterplots (line graphs) based on predictive models. These were used to depict numerous relationships between independent (IV) and dependent variables (DV) such as:

- Number of online sessions attended (IV) / overall student's grade of the term (DV)
- Number of a student's chat interactions in an online session (IV) / deliverables or performance in the session (DV)
- Rating of a student for the online delivery through a survey (IV) / overall student's grade band of the term (DV)

- *Clustering* – e.g. dividing the students into groups based on their preference and achievement for different types of online learning techniques. Again, this method was utilised in this study at the culmination of a full term of data collection from 5 different modules (3 undergraduate classes of 45 students / 2 post graduate classes of 40 students) who received the different online virtual learning techniques described in the subsequent section. Preference was determed through questionnaire surveys, and performance was based on their accumulative grades throughout the term. The clustering learning analytics in this study was implemented by performing detailed analysis of the Linear Regression Scatterplots of the performance, retention and enjoyment results collected for each online delivery method described in the following section, to identify these clusters within them.

- *Relationship Mining* – e.g. to discover the strength of the correlation or association between the Independent and Dependent variables mentioned above. This method was achieved in this study by calculating (for the same sample of undergraduate and post graduate students) the Correlation Coefficient (R) and Correlation of Determination (R^2) for the above mentioned graphs' regression lines. A numerical value 0.7-1 meant a strong relationship / 0.4-0.7 moderate / <0.4 meant a weak relationship. This technique integrated the learning analytics of all 3 methods above

- *Discovery with Models* – this method involves creating a holistic relationship model using the results of prediction and clustering above. This method was not addressed in this paper and will be part of the continuous future research by the author in this area.

- *Distillation of Data for Human Judgement* – this is a graphical visualisation method used for classification of analysed results. This method also was not addressed in this paper and will be part of the continuous future research by the author in this area.

Hence numerical data was collected depicting students' quantity of engagement / interaction in exercises, performance during exercises, deliverables, and their rating of enjoyment from the different online delivery techniques used (described subsequently). This was conducted across 5 modules with a total of 60 under and post graduate students. The results achieved and anlysed using the above learning analytics methods (prediction, clustering and relationship mining) will be explained in the Discussion section after the subsequent Case Studies section, demonstrating the different online novel virtual techniques utilised for delivery of teaching and learning.

Online Teaching and Learning Delivery Case Studies

2D Virtual Learning Environments (2DVLEs)

The first usage for virtual environments that was needed, was to deliver conventional webinars where a presentation was to be delivered with engagement from students in the form of text and/or audio and video feedback from them. While many media in the market provide these capabilities, the adobe Connect platform was chosen instead due to its high flexibility in customising the interface to include as many windows as possible with diverse functionalities and different sizes and locations on screen.

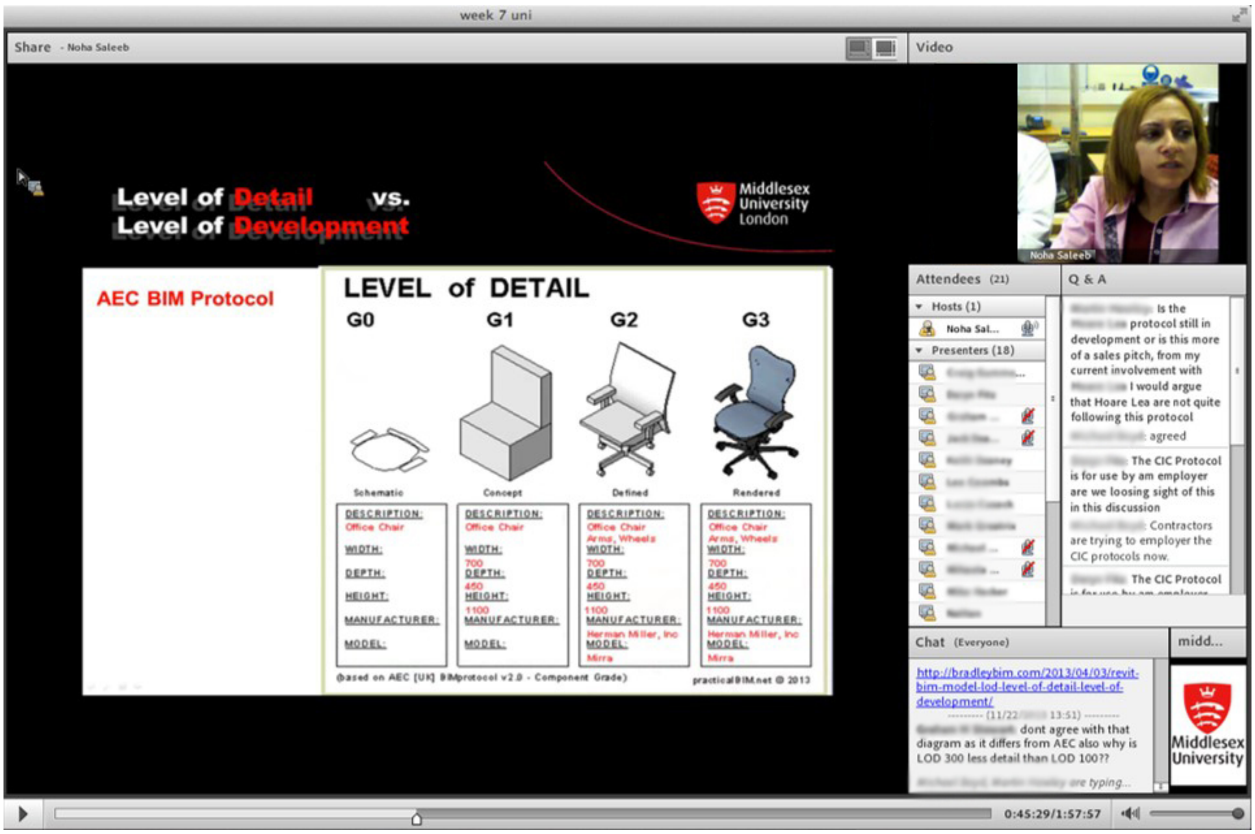

Figure_4: Using Adobe Connect for Virtual Webinars

Figure 4 shows traditional setup with presentation area in the centre, attendees, video and chat windows. However, this interface had capabilities not available in other virtual media to be customised by adding the following:

- A separate Q&A window, so that students specific questions do not get lost in the chat discussion. This window has the capability for each individual question to be answered to in text separately, added to, minimized or even deleted without compromising the other questions.
- A separate window with university logo in it
- The presentation window has the capability to share screen or just a single document or turn into a white board. It is essnential to note that it was possible to have more than one

remote presenter share their screens simultaneously by adding multiple presentation windows side by side.

- In addition to recording the session, the recorded session allows the user to manipulate each section in the recording separately, so one can scroll in the attendees list, or chat log or questions according to preference.

The next step was to make this virtual environment more interactive for students, as can be seen in Figure 5, which shows a live design review and feedback session among students for a 3D model design. The following functionalities were added to the interface:

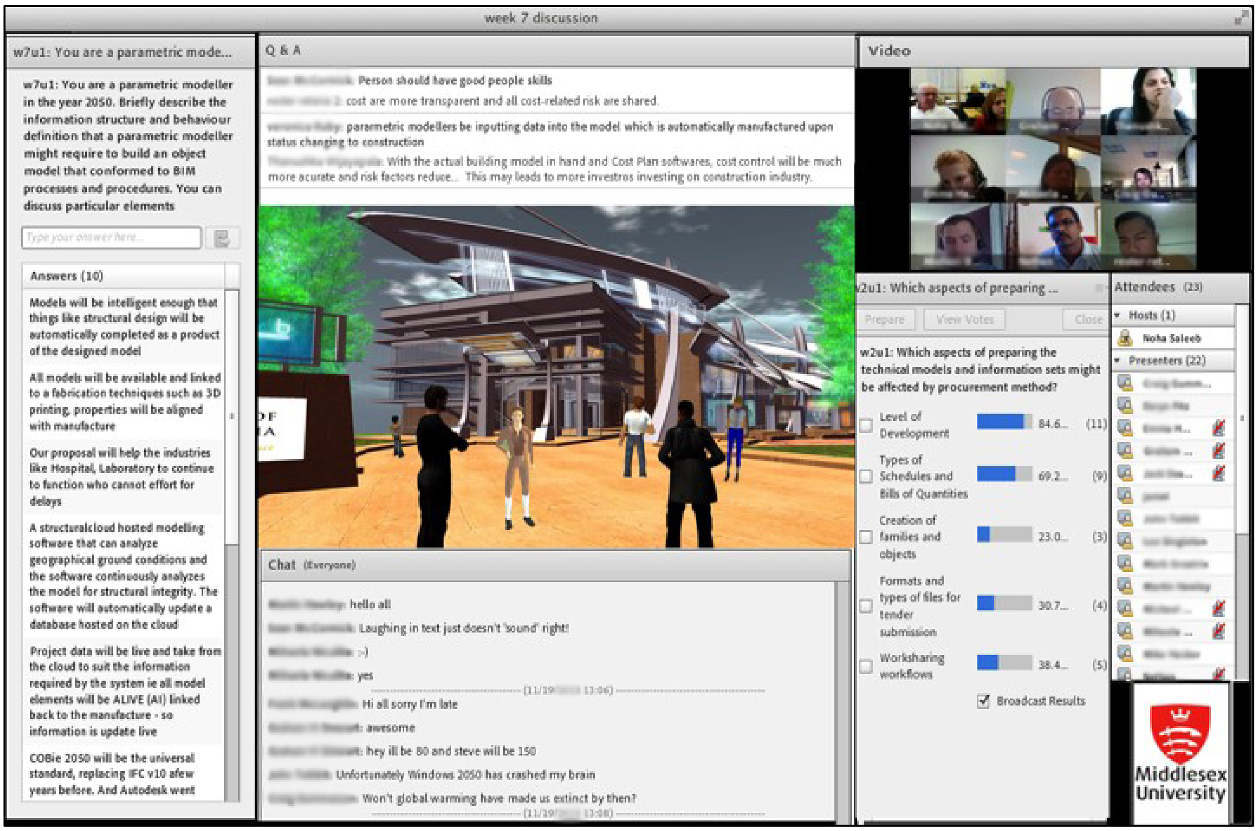

Figure_5: Using Adobe Connect for a Practical Review Debate

- Multiple choice question poll to ask students their opinions about a certain topic
- Open ended question area where students write their replies to a certain problem (as many as these polls can be added)
- The presentation area was sharing a live view inside Second Life where the 3D building model was created, and each student was logged in with their avatar inside there. Using a second screen, the tutor was navigating inside Second Life around and inside the building, and the students were doing the same using their avatars, and they were all commenting on the design from their perspectives and debating in the chat area. Hence each student had

an individual view on one screen, and a merged view on another screen inside Adobe Connect where the debate was taking place.

The students who were all professionals in industry found this extremely engaging and beneficial in collaborative design, and emulating the actual work environment. This has the advantage of increasing students' employability skillsets.

The next step was to allow having more than one team, work in groups simultaneously online. In order to do that, several other functionalities were customised in the Adobe Connect interface to allow having break out rooms or spaces, each dedicated to a different team, as per Figure 6.

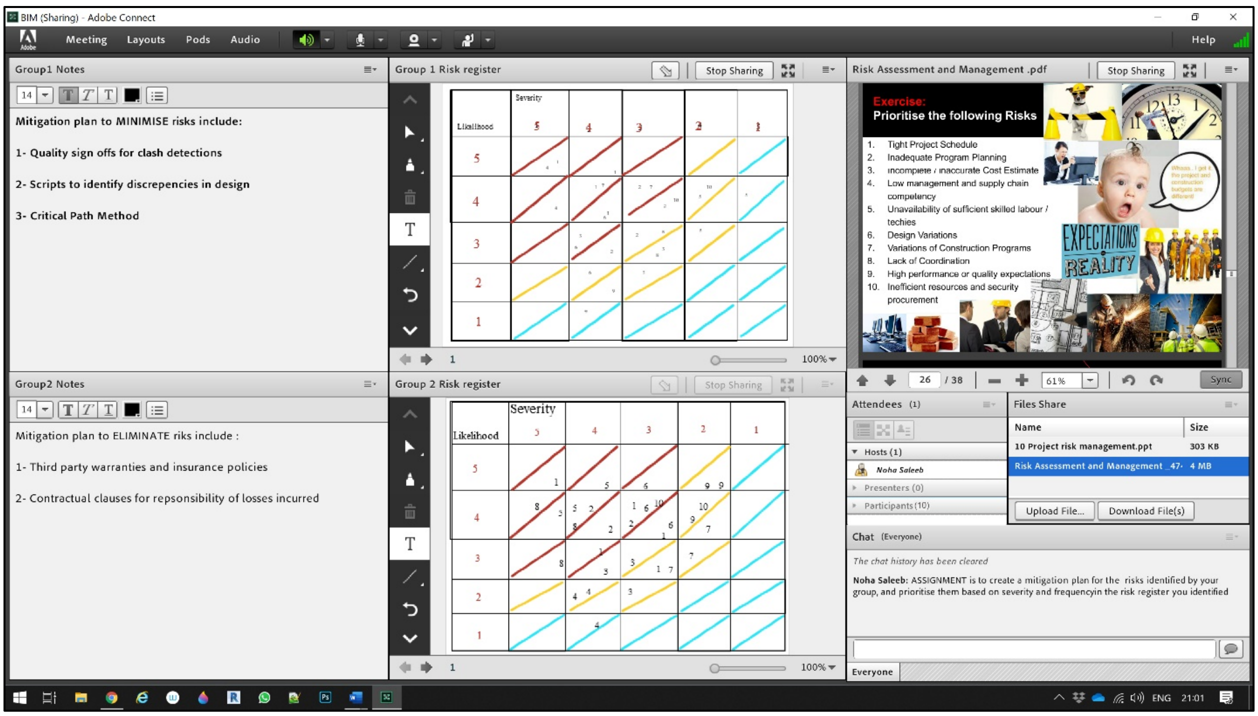

Figure_6: Using Adobe Connect for Break-out Rooms and Group work

The following customisations to the interface were added:

- Each of 2 teams had a dedicated window as a white board to resolve a question posed to them in the chat , and its presentation shown instead of the cam area on the top right corner. The tutor drew the initial risk register in the white board, then all members of each team could type or draw simultaneously on it to enter the risk assessment figures required.
- Each team also had a separate notes area to create the assignment ideas required from them, which would then be discussed with them upon completion. They can customise the text in these areas at will and then later save and send to themselves.
- A separate window was added (mid-right) where the tutor uploaded beneifical documents for them to download and utilise.

- At any point during the session, any of these windows could be hidden or added or their size customised.

The last usage of this 2DVLE was to allow one on one supervision and review of student work, as well as provide practical teaching techniques. Figure 7 shows a design review and teaching session for a student’s graduation project.

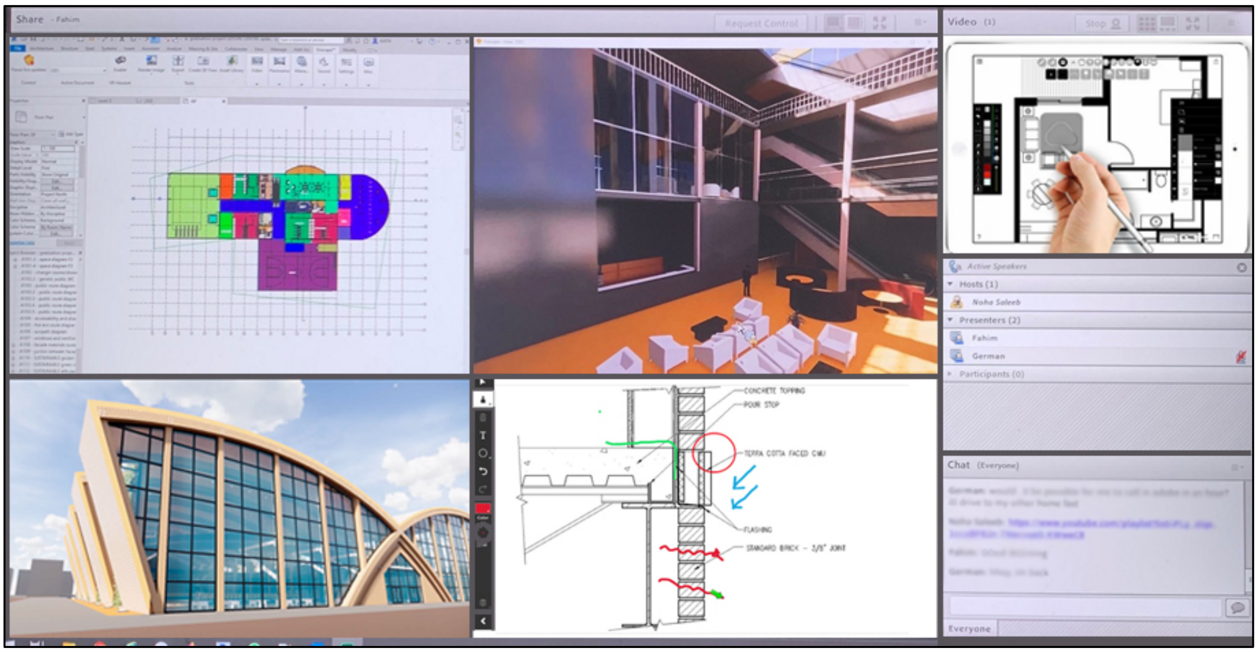

Figure_7: Using Adobe Connect for Design Class

The following was customised in the medium

- Two windows were shared by the student, one containing a plan view of the 3D model in Revit, and the other containing the BIM 360 3D model itself to navigate inside it
- Two windows were shared by the tutor, one containing the animation of the model to control it from the tutor’s end, and the other was sharing the pdf of one of the details in the model that the student sent for review. Both the tutor and student were them able to annotate it and put mark-ups on it live on screen during discussing how to enhance it.
- The tutor also opened their cam to show what they were drawing for the student on their I-Pad.

This allowed quality one-on-one engagement with the student’s practical work and ability to review all aspects of the project, whilst also recording the session for the student to see it again later in case of missing any discussed points.

In addition to using this 2DVLE, other external virtual tools were used to complement the teaching and learning process:

- Slido: allows sending an external question link to students to answer on a web browser, displaying results without a need for opening the 2DVLE. This allows for asking a quick exploratory survey in preparation for class.
- E-Journals: an important constructivist tool, having students write weekly discussion e-journals/forums inside a Course Management System like Moodle, where they initiate a topic related to something discussed during the week, and each add value to it from literature, case studies, experience and evidenced logic. This helps construct and develop their own individualised knowledge-base, in addition to gaining benefit from others' analysis on the topic. Learning analytics showed that this technique was one of the most value-adding on programmes as testified by students.
- Turnitin: this online tool helps detect plagiarism/similarity percentages. However, it also allows providing feedback to students inside it in different formats (text, audio, video).

3D Virtual Learning Environments (3DVLEs)

3DVLEs have been a host for many virtual campuses of universities, e.g. Harvard and Cambridge, since their offset more than two decades ago (Kay, 2009). These virtual media offer innovative opportunities for technologically supported e-learning for many science and arts disciplines. Online avatars allow students and their instructors to interact synchronously by audio, text chat and other 3D media presentation and object creation techniques. A paradigm shift in education, also used in the case studies here, called "Animated Pedagogical Agents uses life-like autonomous 3D characters/avatars that cohabitate the learning environment to provide a rich interactive face-to-face interface and activities with students who are also embodied in the learning environment as avatars (Nunes et al. 2010).

In compliance with achieving the preceding pedagogical theories for attaining deep, effectual and constructivist e-learning, came the design concept of creating the Middlesex University Island inside Second Life as the chosen 3DVLE. Three connected learning spaces/buildings were created by the author that can cater for different modes or needs for collaborative learning as per Figure 8.

Amphitheatre: for general lectures for 100+ students, based on server allowances within Second Life to hold such a number of simultaneously logged in users on one "sim" or island (Smith, 2008).
Seminar Hall: for discussions and debates along with lecturing, for 40 students, with formal and informal setting of seats.
Classroom for collaborative hands-on activities for 20 students.

Following are different options for teaching and learning that were performed in these virtual spaces within different programmes:

1. "Rezzing" (materializing) objects during presentation for teaching, simulations e.g. Robot
2. Immersive tours in unreachable places (modelled inside the 3DVLE): mountains, underwater, space, inside atom, cell, volcano, body
3. Simulations: nuclear explosion, lab reactions, air and car traffic, hurricanes, human operations, canon trajectory

Figure_8: Virtual Learning Spaces on Middlesex University Island inside Second Life

4. Students create and interact with objects using programmable scripts to
    - Create robotic simulations
    - Test network systems
    - Circuit and microchip design and testing, coil, magnet & wave visualization
    - Product design, real-time CAD design (buildings & motor machinery)
    - Representation design, HCI usability
    - Artificial intelligence bots
    - Link between web and SL e.g. e-commerce
    - 3D graphics and game creation

- Database systems creation

5. Work based learning scenarios, interviews, business model trials, staff training
6. Role playing e.g. forensics, law court, knowledge business meetings scenarios, paramedic emergencies
7. Scavenger hunts to find clues hidden inside objects to build knowledge
8. Private chat channels, chat logs
9. Streaming music during teaching
10. Sharing web links, note cards to avatars, answers
11. Camera control tools like Camsync to ensure students are looking at the appropriate feature
12. Presentation boards that allow students to add push pins on selected slides to indicate choices – hyperlink to other in-world places and websites
13. Shared media web tools updated synchronously – students participate in making lists, diagrams
14. 3D mindmaps to model progress of lecture as you go
15. Automatic generation of 3D bar or pie charts – immediate polls and surveys
16. Students can change location for different exercises in same session
17. Have guest speakers participate remotely
18. Inworld timer to countdown when asking questions and not accept late answers
19. Give audience gestures and sounds to play when appropriate
20. Delivering pre-prepared text chat for audio impaired students
21. Visually impaired students can have inline text to voice conversion
22. Multi-lingual translators
23. Multiple interactive screens – collaborate in real-time – drawing, multiple websites, multiple quizzes, games
24. Follow up and assessment: Weekly meetings, In world quizzes, Office hours, Participation and feedback logs, Self and peer assessment

Artificial Intelligence in 3DVLEs

Along with creating solid or hollow inanimate objects in Second Life, it is possible to place programmable scripts on created objects to give them specific repetitive animations, or provide the objects with Artificial Intelligence (AI) awareness of the surrounding actions and events and hence react according to different situations and stimuli. This is done by placing the scripts on an object attached to an automated avatar (bot), and this object runs the script and controls the avatar to appear to walk, talk etc. (Friedman et al., 2007), do simple interaction tasks e.g. recognise approach of other avatars, ask questions, provide pre-prepared answers to questions, follow, lead, locate other avatars, turn on/off other objects, play pre-recorded animations as responses to different stimuli, collect data or information, and simulate roles e.g. patient, waiter etc. (Ranathunga et al., 2012). These appear as realistic avatars, which belong to real-life users, thus as indicated by Varvello and Voelker (2010) can be used to conduct endless activities, social interactions and experiments at any time of day with precision.

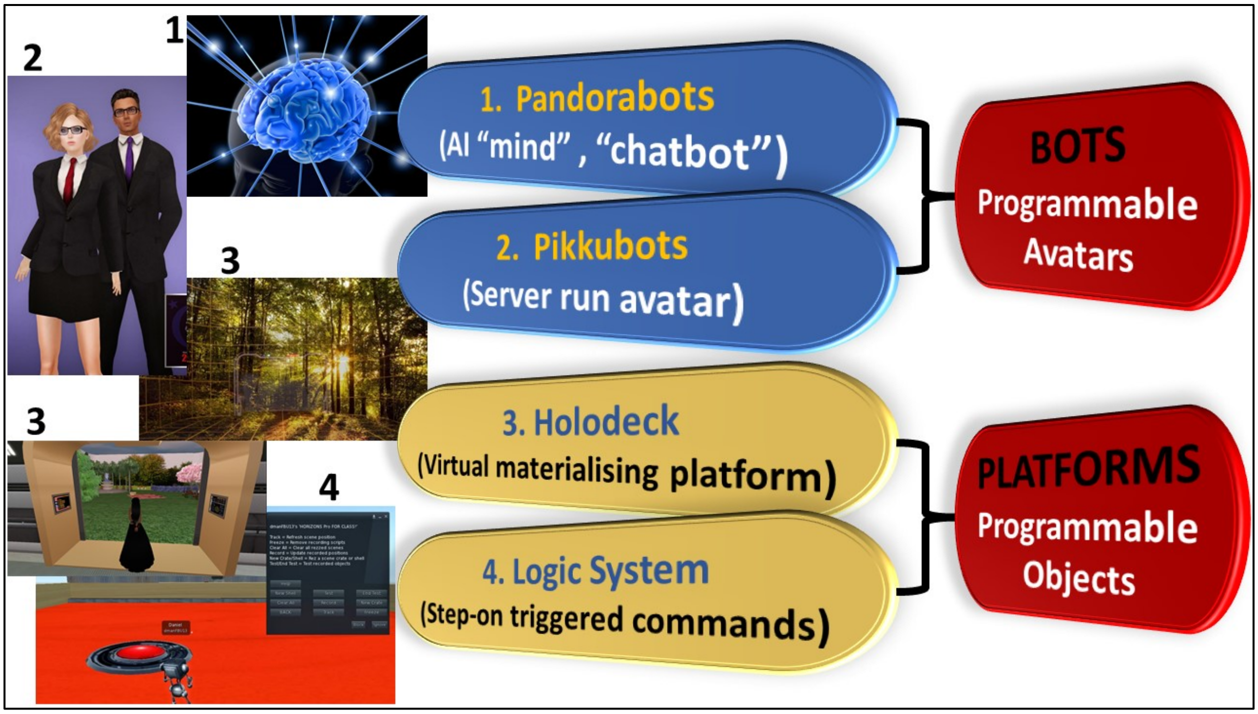

Figure_9: Artificial Intelligence Components inside 3DVLEs

For the purpose of this study, 2 different kinds of bots were experimented with: "Pandorabots" and "Pikkubots". These were used in association with a simulation "holodeck" and "Logic System" as per Figure 9:

Pandorabots are AI "minds" or "chatbots" created using a free open-source website enabling development and publishing of these chatbots anywhere on the web, including 3DVLEs like Second life. These support AIML 2.0 as their knowledge content markup language, which is easy to program/trained to provide certain sets of answers when asked certain combinations of questions or keywords.

PikkuBots are bots/avatar entities created for Second Life which can be operated automatically. They need a program that is installed on a dedicated server to automatically run inanimate avatars in Second Life even when the user is not at the computer. The PikkuBot can be configured to do many tasks. After installing and configuring, the bot is controlled using "commands". These are short words sent to it either using the instant messaging chat inside Second Life, typed in the command line at the bottom of the bots' GUI, or using commands sent to it directly using an inworld scripting engine placed in a concealed or visible object – Logic System - which triggers the command when the bot steps on it. The bots interact in the environment by sending action commands back to the server and the character moves, talks etc. (Johnson et al., 2000).

Holodecks are virtual reality platforms which can take the form of any object inside a 3DVLE but contain scripts to "rez" or materialize/create an immersive new environment around the avatar. This can be used to provide multiple alternate environments or realities, through choice from a menu, which students can engage with.

All 3 AI components mentioned above were used for the pedagogical project scenarios presented below. The technique used was 1)_Create a Pandorabot mind and train it to recognise a series of questions using combinations of keywords, then provide groups of specific answers for the bot to reply with. 2)_Create an inanimate Pikkubot in Second life, customise its appearance and place the Pandorabot AI mind on it (attach it to it) to give the Pikkubot the life-like interactive conversational abilities to communicate with other real users' avatars. 3)_Program a scripting engine in Second Life, which when stepped on will animate the Pikkubot's physical actions e.g. move, point etc. 4)_Create/ script a Holodeck, build and compress all the environments/spaces/buildings which are to be rezzed from it, then place these environments inside the holodeck and script its menu to materialize them on demand. 5)_Adjust the scripting engine controlling the Pikkubot so that one of its commands would make the Pikkubot trigger the holodeck and rez a specific environment based on the questions and answers dialogue with the real avatar users. 6)_Devise the different project scenarios to be used with the students, utilising the above created comprehensive AI system comprising of Pandorabot, Pikkubot, scripting engine, built spaces and Holodeck. Examples of these projects are demonstrated in Figure 10.

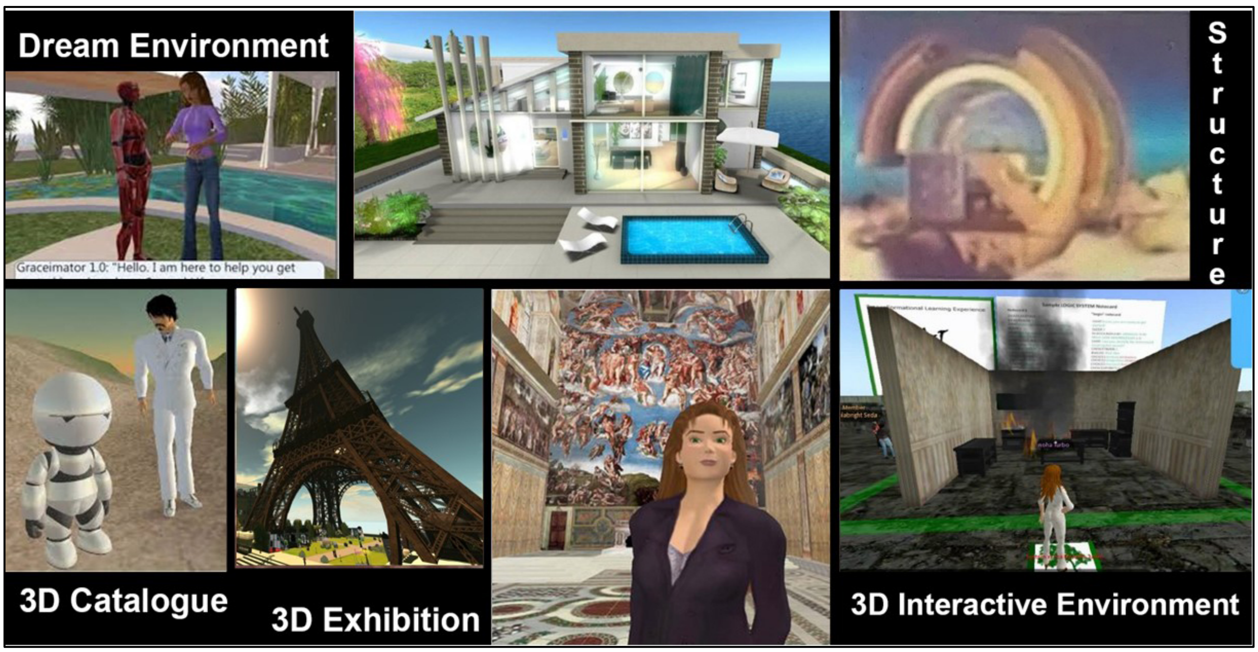

Figure_10 Artificial Intelligence Project Scenarios inside 3DVLEs

Dream Environment was a project related to digital creativity and design modelling. The purpose of this was to allow the students in a 3D environment to change the building style they are in to study different elements of architecture related to a certain era e.g. in an Egyptian, Chinese, Indian, Roman, Classic style temple or building. The building prototypes would be created then loaded inside a Holodeck (a commercial example of which is "Horizon Holodeck"). The student or tutor can choose whatever environment he wishes for to open up around him from a menu that appears for him inside Second Life. A Pikkubot would then appear, as shown in Figure 10, dressed appropriate to the era chosen and provide information about the architecture and design, asking questions interactively from the student. Other applications of this system can be e.g. to rez a courthouse to conduct forensic studies investigation and role-play.

Virtual Tourist is another project using the same technology to teach students about different touristic places on Earth, dangerous places or historical extinct places (could be used by any tourist unable to visit these places due to disability or time) by modeling (simulating) these places e.g. Pyramids, Eiffel tower, Everest Mountain, North Pole, Pacific Ocean, Solar System, placing them in the Holodeck then rezzing them at will, or teleporting to them if they are already modelled in Second Life. A Pikkubot would explain, provide a virtual tour and question the students. Not only can one build an environment to rez, but also a real-life panoramic view can be placed in the Holodeck, which would rez around the avatar and create a feeling of immersion inside it (Figure 11 environments 4-8).

3D Catalogue involved creating a complete application for use by a real estate company (houses to buy/rent), where the user talks to a Pikkubot (representing an agent). The user specifies the house size he wants, number of rooms, price range etc., and automatically samples of model house appear before him to choose from (from a holodeck) as can be seen in Figure 10. This has potential of being an online service for a real-life business.

3D Exhibition is a project similar to the above but displaying a gallery of renowned images in the Louvre with spoken info by a Pikkubot on each.

3D Interactive Environment uses the Holodeck to create interactive environments e.g. how to set up alarm system, piping system, health and safety precautions. Figure 10 illustrates a rezzed kitchen using Holodeck. It is the Pikkubot asking questions like what to do in case of fire hazard. If answered correctly it makes a flaring sound, if not the kitchen goes on fire, then system can be reset.

According to Maher and Gero (2002), agents or bots can function in three modes: reflexive (bot responds to sensory data from the environment with a pre-programmed response or reflex without any reasoning), reactive (bot displays ability to reason/respond according to the input data, displaying a limited form of intelligence giving different responses from training for different situations), and reflective (bot exhibits capacity to "reflect" on input and propose alternate actions or decisions). The projects above demonstrate reflexive and reactive behaviour from the bots, but not reflective, which can be the next step in future projects.

During their engagement in each project, students were asked to fill questionnaires as note cards in Second Life to comment on their experience and interaction. An automatic chat log of the participants' interactions with the bots was analysed, and merits/difficulties recorded to enhance future projects. All projects showed high interest from students. The main difficulties were time required to code and prepare by tutors, and usage of system by students. Hence a prerequisite was to have an hour training/orientation session for students on using the systems before deployment. The main merit recognised by the students was participating in an interactive, engaging "live experience" where they could embody their character, cooperate with others and submerge themselves in an experience that could not be replicated as fully in real-life. Additionally, the free-form nature of Second Life meant that each session/lesson could be different, allowing for different situations to be played out depending upon the contributions of the participants.

As can be seen, these projects achieved deep learning through synthesis and understanding of the projects' context, and also satisfied the 7 principles of constructivism through student/task-centred activities that rely on students' individual experience to construct new knowledge.

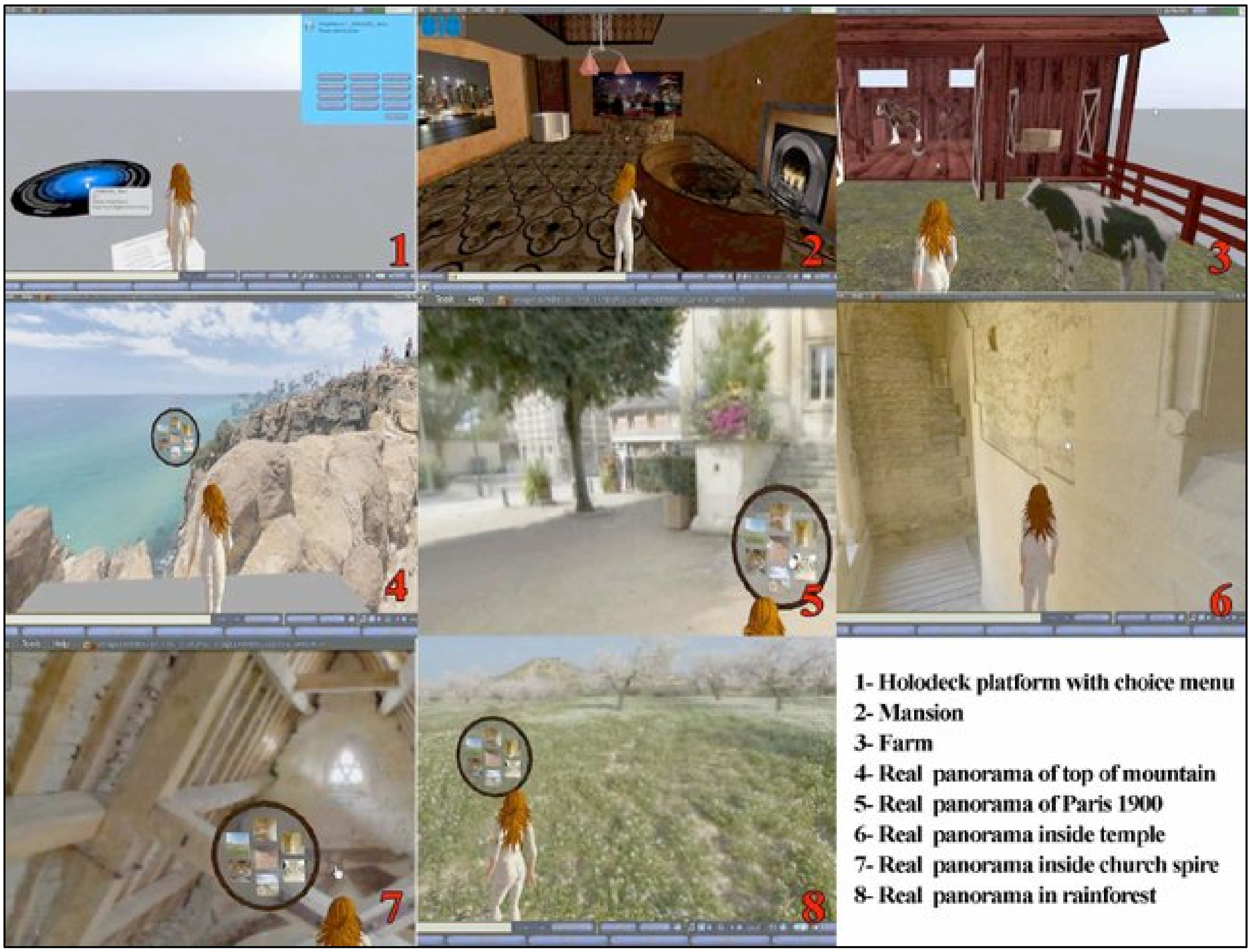

Figure_11: Holodeck and different virtual environments rezzed from inside it using a choice menu

Haptic, Virtual Reality and Augmented Reality Technologies

Haptic technologies utilise actuators to apply force feedback to the skin, giving the student a direct contact with force feedback to the skin. This can be understood as 'real' world touch contact with physical objects, which occurs when the user experiences touching a visual object on screen coupled with actual haptic force touch. Users can be given different force types to interpret as different surface types e.g. a smooth flat plane, a soft, hard, sticky, rough surface etc. (Reid et al., 2019).

This technology can be utilised in future projects for blended learning, where haptic tooling can be implemented within the design development process where learners experience hands on learning. Students can interact with objects via a specific haptic tool (e.g. Geomagic Touch™ – a single point of contact device), which will work in combination with a CAD interface to help design materials and surfaces.

Furthermore, technology-aided instruction, is focusing more on Virtual Reality (VR) and Augmented Reality (AR) technology due to its ability to support immersive learning, teaching through simulation, and gamification of learning. These systems can deliver high-level multisensory learning experiences that are important in the teaching of many subjects, especially those requiring spatial skills (Edwards et al. 2019)

VR and AR can be utilised in future blended learning projects by developing an immersive learning environment within a VR head-mounted display, where students engage hand movements to build asset models and spaces and experience haptic feedback through gloves with built-in sensors and hand-tracking. This will allow better perception of the designed spaces with more detail and understanding given to materials etc.

Discussion

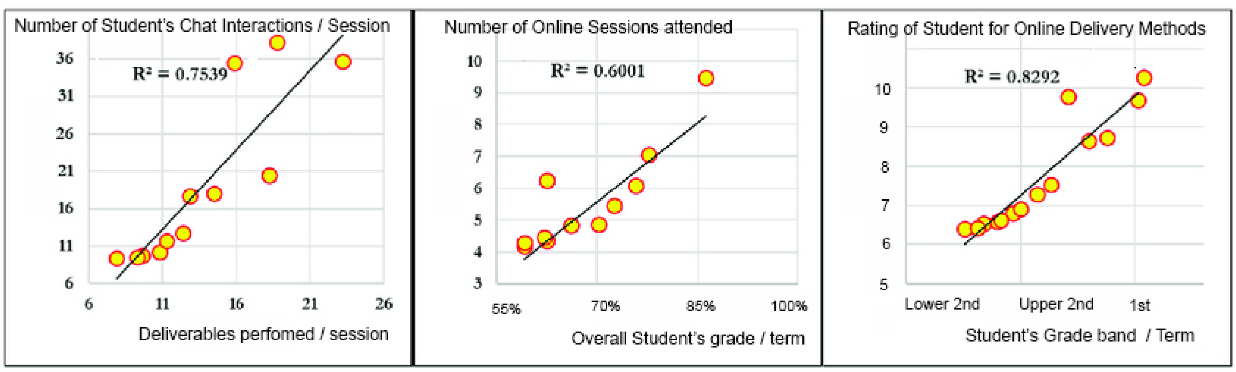

Figure_12 Results of Linear Regression Scatterplots created from data collection

During conduction of the online virtual teaching techniques described in the case studies above, 3 sets of data were collected from each of 5 teaching modules. The mean of all the results for all the modules and techniques are shown in Figure 12 above. A linear Regression Scatterplot was created for each dataset, and a Correlation Coefficient (R) and Correlation of Determination (R^2) was calculated for each of the graphs' regression lines. Analysis of the results showed the following:

1. The 1st graph depicts the relationship between the number of chat and audio interactions each student had with the tutor and their peers during the session (independent variable), and the number of performed tasks the student delivered during the same session based on exercises/learning outcomes defined by the tutor (dependent variable). The results of R and R^2 reveal a strong correlation between the 2 variables (>0.7), which could provide strong evidence that the more the students engaged in the virtual learning environment, the more that had a positive effect on enhancing their performance, which is the first research question.

2. The 2nd graph in Figure 12 depicts the relationship between the total number of online sessions attended by the student per module (out of total of 10 in the 2nd term delivered online after national lockdown due to global health crisis – independent variable), and the student's overall grade for the 2nd term (dependent variable). The results of R and R^2 reveal a moderate correlation between the 2 variables (0.6), which could indicate that the more the students engaged in the virtual learning environment, the more that had a positive effect on enhancing their performance, which is the second research question. Of course other factors could have affected the results e.g. the students non-familiarity with the online medium early on in the term and requirement for training on it / poor bandwidth preventing the students from fully engaging in the experience etc.
3. The 3rd graph in Figure 12 depicts the relationship between the rating that each student gave for the level of their enjoyment from using the online learning technique (independent variable), and the grade band they achieved at the end of the term (dependent variable). The students rated the level or enjoyment / practicality / usefulness on a scale of 1-10 through an online questionnaire. The results of R and R^2 reveal a strong correlation between the 2 variables (>0.7), which could provide strong evidence that the more the students felt enjoyment and value in using the virtual learning environment, the more that had a positive effect on enhancing their overall grades and retention, which is the third research question.

In terms of Learning Analytics "Prediction" and "Clustering"– there is strong evidence displayed from the results that there is a positive impact of using online virtual learning techniques on the learning experience of students in terms of retention, performance and enjoyment, which is analogous to results obtained from pure physical face-to-face learning techniques. This is based on the similarity between student grades obtained in 1st term and 2nd term of the academic year, when all teaching had to be delivered online due to the global health crisis. Detailed analysis of each scatterplot graph indicated the clusters of students who preferred different techniques to others. This was helpful in identifying which online method to use more extensively and to be customised further with the students of different modules.

In terms of Learning Analytics "Relationship Mining" - there is again strong evidence displayed from the results that there is a positive impact of using online virtual learning techniques on the learning experience of students in terms of retention, performance and enjoyment due to the high R and R^2 results obtained and explained above. The R and R^2 results pertinent to each individual online learning technique and type of taught module is outside the scope of this paper and discussed in a separate publication.

Future continuation of this research would involve comparing between the results of the physical and virtual learning techniques, comparing between results of different types of modules, in addition to using the 2 remaining methods of learning analytics, i.e. "Discovery with Models" and "Distillation of Data for Human Judgement".

Conclusion

This paper highlighted novel case studies of using different types of 2D and 3D Virtual Learning Environments to deliver online remote teaching and teaching, highlighting the pedagogical principles adopted to design the virtual sessions to achieve the programmes' learning outcomes. The paper hence highlights the implications of this research and importance of using Learning Analytics in assessing the efficiency and success of using the adopted online virtual techniques to improve students' educational experience (Dawson et al. 2019). The results obtained, as demonstrated previously, with quantitative and qualitative learning analytics performed showed a high engagement of students in the activities and enjoyment in the experience, with retention and formation of new knowledge, which demonstrates the implications and benefits of this research.

The results presented and discussed in the previous section provide evidence for the main research question regarding the effect of using innovative virtual learning techniques on students' learning, performance, engagement and participation. Results showed that the more the students interacted in the virtual learning environment, the more that had a positive effect on enhancing their performance (previous results discussion point 1). Also that the more the students felt enjoyment and value in using the virtual learning environment, the more that had a positive effect on enhancing their overall grades and retention (previous results discussion point 2). Upon initial training of the students on the utilisation of these platforms, students were able to achieve deep constructive learning using the mix of 2D, 3D and AI tools, due to these being engaging, diverse and giving a sense of ownership for the space (previous results discussion point 3).

Hence, generic implications of this research demonstrate that utilisation of the techniques described in this paper, in educational institutions of all levels, can help deliver engaging and productive educational experiences for students, especially in case of non-ability to attend in person or in case of emergencies (e.g. recent global lockdown due to health crisis).

Future addition to these case studies will be to involve the students' touch sense in addition to the audio and visual sense online, and that is using haptic technologies as explained previously. Virtual and Augmented Reality immersive environments can also be utilised to allow for better spatial design and details. This is in addition to evolving usage of AI bots to be more reflective in assignments in 3D VLEs. Also usage of 2DVLEs to remotely access cloud services and software to allow real-time actions, processing rendering to occur. For example, rendering models and sustainability simulations immediately during sessions to discuss different options.

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