Using Game-Based Learning in Virtual Worlds to Teach Electronic and Electrical Engineering

Michael J. Callaghan, Kerri McCusker, Julio Lopez Losada, Jim Harkin, and Shane Wilson

Abstract—**In recent years there has been significant growth in the use of virtual worlds for e-learning. These immersive environments offer enhanced distance learning facilities where students can participate in individual and group activities, using advanced communication tools, inside complex and highly interactive simulations. Video games have entered the mainstream as a popular entertainment format and are starting to be adopted as teaching tools. This paper explores how virtual worlds and video games techniques can be used to create highly immersive and engaging environments for teaching engineering related material. It will show how the presentation layer of remote laboratories, which are traditionally 2-D in nature, could be enhanced by the use of 3-D to facilitate new types of remote interactions and methods of visualizing and interacting with data. The Circuit Warz project is introduced and demonstrates how immersive virtual worlds can be used to create a game based approach to teaching, which supports and complements traditional delivery methods using a collaborative team based competitive format with an underlying hardware infrastructure.**

Index Terms—**Engineering education, game based learning, hardware integration, remote laboratories, virtual worlds.**

I. Introduction

THE constant emergence of disruptive technologies continues to offer new and exciting opportunities for educators [1], [2]. Developments in recent years have seen web-based virtual learning environments (VLE)/course management systems (CMS) rapidly become an integral part of teaching and learning provision in further and higher education [3], [4]. This evolution progresses unabated as educators strive to adopt and adapt web 2.0 technologies in the provision of more interactive teaching materials and learning environments [5].

Video games and virtual worlds (VW) are moving into mainstream education, mirroring worldwide trends where traditional media industries struggle to keep up with digital natives and their desire for information, technology and connectivity [6], [7]. The use of games in education is growing, where game play mechanics are used for non-game applications. This process is accelerating as educators learn to make effective use of the most appealing features of computer games e.g., active participation, intrinsic and prompt feedback and challenging but achievable goals [8]. Remote experimentation facilities offered as part of a web-based learning approach affords a number of critical benefits, augmenting and complementing web based learning material by facilitating distant access to campus based physical resources [9]. For engineering related distance education courses the use of a web based delivery mechanism is the only realistic method of providing practical hands-on experience, allowing remotely located students to complete laboratory assignments, unconstrained by time or geographical considerations while developing skills in the use of real systems and instrumentation [10], [11]. Remote experimentation laboratories have evolved in recent years, expedited by advances in web applications and related technologies, where the end objective is to accurately recreate the on-campus laboratory based student experience with an equivalent level of user access, functionality and flexibility. The use of VW and mixed reality in this context has facilitated collaborative, group based working in immersive 3-D environments, allowing students to interact and visualize complex simulations and data sets in new ways [12].

These individual approaches have proved to be useful tools for educators; however no real attempt has been undertaken to date to explore the potential opportunities offered by combining all of these individual elements together. This paper explores how all of these individual components can be successfully integrated to create a highly innovative, state of the art environment for teaching engineering related material with potential for widespread use across multiple domains and subject areas. It shows how to create a deep integration between a VW, a VLE and complex external hardware/test instrumentation allowing the educator to create highly structured, experiential based learning experiences for students where interactions and activities are managed by and recorded back into the VLE. Additionally this paper demonstrates how the existing environment was further enhanced by adding a game based layer, inside the VW allowing teams of students to work together collaboratively/competitively to bias electrical circuits as part of a practical based learning exercise. The resulting architecture, while complex and made from many components, demonstrates the validity of the approach taken and its potential for widespread use across other disciplines.

Section II of the paper discusses recent research in VWs at the University of Ulster and provides an overview of how VWs can be used as a highly interactive and immersive layer for VLEs. The Engineering Education Island project is introduced and the process of integrating VLEs and VWs shown. Section III looks at the creation of a unified learning experience integrating VLEs and VW using this approach. Section IV shows how this environment can be extended to integrate, control and access remote

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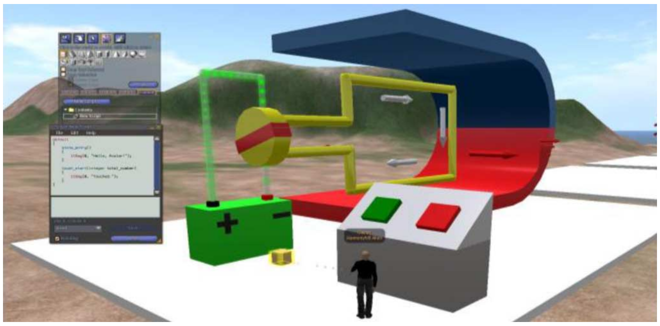

Fig. 1. Content Creation in Second Life.

hardware and visualize data using VLEs. Section V shows these elements combined together to create student focused collaborative and competitive game based immersive learning experiences. Section VI looks at initial evaluation of these approaches. Section VII concludes the paper.

II. Virtual Worlds as Teaching Tools

Internet-based 3-D VWs are immersive environments which facilitate an advanced level of social networking where residents can explore and socialize by participating in individual and group activities [13]. While 2-D games and simulations have proven useful as complementary teaching and learning tools, 3-D VWs have a number of advantages when compared to 2-D. These benefits include conducting educational activities in a risk-free environment, enhancements in collaboration and communication, increased learner engagement and the visualization of abstract ideas [14]. 3-D VWs have proven an ideal platform for collaborative group based learning particularly for distance education students where the physical presence of avatars in a shared space, with real time communication facilities offer more engaging student experience with a better sense of physical presence [15]. Communication is improved by the use of avatars which facilitate non-verbal communication cues and emotions in real time allowing more natural interaction [16]. Students have demonstrated higher levels of engagement in VWs spending more time interacting with and discussing subject material [17], [18]. These environments allow learners to interact with teaching material in first person facilitating constructivist-based learning activities and developing stronger conceptual understanding of material [19], [20].

Second Life (SL) is an Internet-based 3-D virtual world launched in 2003 and developed by Linden Research where residents interact with each other through motional avatars. SL facilitates an advanced level of social networking where residents can explore and socialize by participating in individual and group activities [21]. SL was chosen for this project as it is popular among educators and has a large and engaged user base. SLs main advantage is that it allows residents, using in-world user friendly and free 3-D modeling tools in conjunction with the Linden Scripting Language (LSL) for programming, to create highly interactive content and user experiences (Fig. 1). Users create basic 3-D shapes called Sculpted Prims which can be scaled, deformed and linked together to form complex 3-D models.

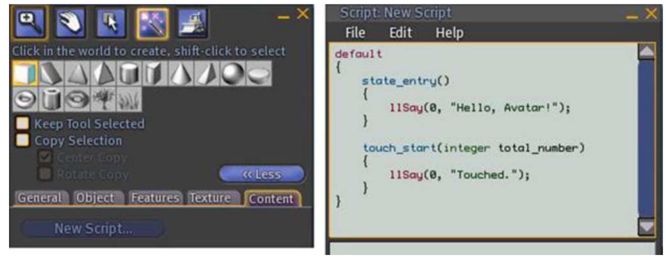

Fig. 2. In-world content creation tools for modeling and scripting.

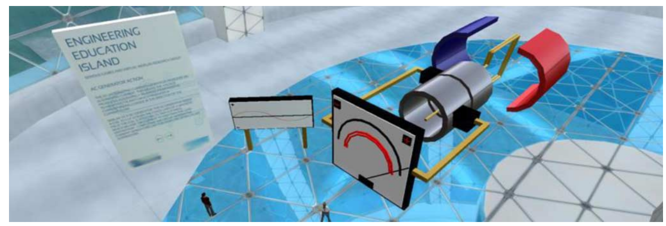

Fig. 3. AC generator demo inside the virtual engineering laboratory.

LSL is used to control the behavior of in-world objects (Fig. 2) enabling tightly prescribed learner interactions. This approach and the simplicity of the tools allows multiple users to work together collaboratively to build and interact sharing creation/editing rights to the content created. Content ownership initially resides with the creator however they can transfer ownership if desired. This allows for the relatively straightforward creation and sharing of additional content and interactive simulations in the VW. Flexible content creation tools, transferrable intellectual property ownership and the fact that basic membership of SL is free has fostered an active educator community and there are now many educational institutions using the environment for distance learning [22].

The Serious Games and Virtual Worlds research team at the Intelligent Systems Research Center at the University of Ulster focus on the potential of VWs for undergraduate (Level 6) and postgraduate (Level 10) teaching of electrical and electronic engineering related subjects [23]. In this context the Engineering Education Island project was created to investigate how VWs could be used effectively for teaching and learning in this domain with a specific focus on the creation of complementary learning resources which explore and explain some of the fundamentals principles underpinning these disciplines to support first year undergraduate students. The environment created contains a range of highly interactive engineering demonstrations and simulations (Fig. 3), which can be explored collaboratively by groups of remotely and diversely located students working together and allowed the project to explore the perceived benefits of using 3-D VWs for teaching. However while VWs can provide a highly engaging, flexible and immersive presentation layer for creating complex simulations, they tend to lack the structured learning and assessment framework and course management features available in learning management systems e.g., Moodle, an open source e-learning platform [24]–[26].

Ideally a solution to these shortcomings would be to leverage the relative strengths of each individual platform through

PRACTICAL 1	Become familiar with the theory and operation of DC generators	
STUDENT NAME	Kerri Macchi	
TASKS	LEVEL OF COMPLETION	
Enter virtual world and go to interactive simulation	Completed	Not Completed
View video in world about learning outcomes	Video viewed	Video not viewed
View slide show showing tasks	Slides viewed	Slides not viewed
Press button 1 to turn on power	Interaction 1 Completed	Interaction 1 not completed
Press button 2 to observe magnetic fields	Interaction 1 Completed	Interaction 1 not completed
Overall percentage of tasks completed	XX% Completed	
Total time student spend on assignment	XX Hours XX Minutes	

Fig. 4. In-world learner centered activities.

Fig. 5. Proximity sensor and feedback to student.

integration. The SLOODLE open source e-learning software project (Simulation Linked Object Oriented Dynamic Learning Environment) enables interoperability between a VW and a VLE (Moodle) facilitating the exchange of data between the two environments [27]. Initially the interactive demonstrations and simulations created on Engineering Education Island did not have any explicit user objectives, formal structure or learning outcomes and had no means of recording user actions/interactions. To address these issues a number of projects were redesigned to include integration between the VW simulation and the VLE, Moodle. Moodle provided structure for the learning experience by presenting learners with course material, specific learning objectives and practical tasks to be completed using the simulations into Moodle. The redesigned courses required registered students to log in to Moodle and review the learning/course material, after which students were directed to enter the VW and complete a range of task based activities, either individually or as part of a group each of which related to a specific learning objective (Fig. 4). In the simple practical demonstration shown above the student is required to understand the operation of an AC generator, its individual components and interactions.

While the ability to communicate between Moodle and SL existed through SLOODLE, the functionality to detect and record learner interactions with objects in the VW did not. To achieve this, two simple extensions to SLOODLE were created, a proximity sensor to record a registered avatar's visit to the simulation in the VW and a real time tracker which recorded in the VLE, learner interactions with VW simulations (Fig. 5). These extensions allowed the recording of the level of student engagement, achievement and interactions in both the VLE and WV (Fig. 6) creating a unified model and record of a student's

Assignment

Object Name	Task Description	Level of Completion	Date
Task 1	Enter virtual world and go to interactive simulation.	Completed	April 11, 2009, 1:30 pm
Task 2	View video in world about learning outcomes	Completed	April 11, 2009, 1:30 pm
Task 3	View slide show showing tasks	Completed	April 11, 2009, 1:30 pm
Task 4	Press button 1 to turn on power	Not Completed	-
Task 5	Press button 2 to observe magnetic fields	Completed	April 11, 2009, 1:30 pm

Overall percentage of tasks completed:80%

Fig. 6. Feedback to student on progress in practical 1.

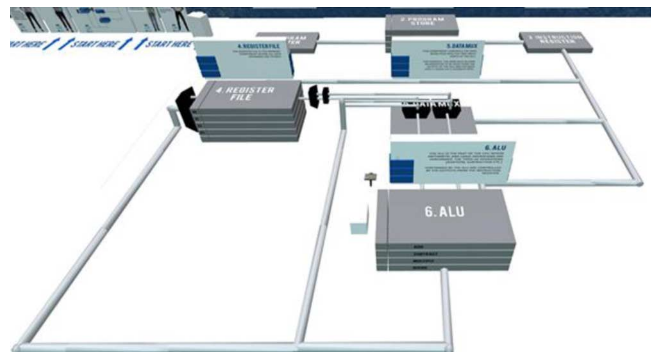

Fig. 7. Fetch, Decode and Execute cycle of a CPU.

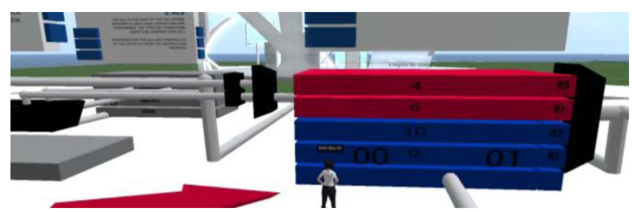

Fig. 8. Decimal values 4 and 6 on the register file.

Fig. 9. Result 24 displayed from the ALU.

learning experience across both environments for later review and assessment.

Once the technical challenges of integrating the VLE and VW were addressed the focus moved to designing more complex simulations and embedding these within a formal pedagogical structure with greater emphasis on assessing student understanding of the underpinning theory using VWs.

III. CPU Fetch-Decode-Execute Cycle

To explore the flexibility and potential of the approach, a more complex simulation based on the operation of the Fetch/Decode/Execute cycle of the Central Processing Unit (CPU) was created. This demonstration was created to complement existing teaching material presented in the VLE and assist students

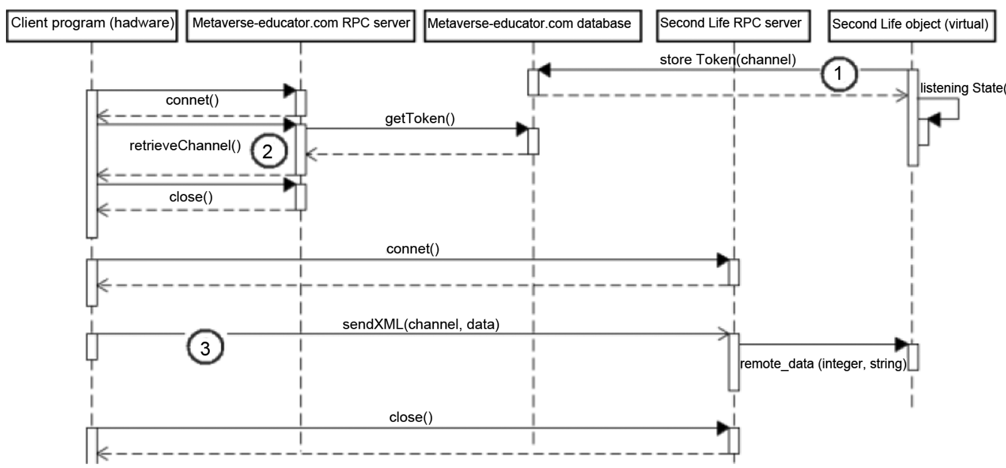

Fig. 10. Sending data into the virtual world.

in understanding/visualizing the internal conceptual layout of the CPU and the data flow within (Fig. 7).

To create this simulation each constitute component of the cycle was broken down and replicated as a series of interacting blocks. These blocks represented and recreated the steps undertaken in a CPU during the execution of a single instruction and the interchange of control and operand information between the various building blocks of the CPU i.e., program counter (PC), program store (PS), instruction register (IR), operand memory (OM), data mux (DM) and arithmetic and logic unit (ALU) [28]. The six basic CPU steps in the multiplication of two operands are included. After reviewing the e-learning material in the VLE, students were presented with a set of practical tasks to complete using the VW CPU simulation. The SLOODLE tracker was used to monitor student interaction with the simulation and record information relating to the student's learning experience back in the VLE. Upon entering the VW students were presented with supporting teaching material detailing the purpose of each element of the CPU and the practical tasks to complete at that stage of the cycle. Students were required to interact with and control each stage in the cycle i.e., input a starting value and follow the subsequent fetch and decoding cycle e.g., show the PC indexing the PS with a starting hex value of '00', output the 8-bit contents of its memory (hex value '68'), feed this value into the IR and see how it is partitioned into four 2-bit values; $A = 00$, $B = 10$, $C = 10$ and $D = 01$ where the 2-bit values A and D are used to index the OM. The decimal values '4' and '6' are outputted from the OM to the data mux where they will be fed into the ALU (Fig. 8).

Then the 2-bit value B (10) tells the DM that the resultant value from the ALU is to be stored back in the OM when the ALU is finished. Finally the 2 bit value C (10) tells the ALU that a multiplication operation is to be performed on the data present at its inputs. The ALU performs the multiplication of 4×6 to provide the computed decimal value of 24 (Fig. 9). Initial executions of the simulation were used to reinforce the students understanding of the underpinning theory. To evaluate the student's understanding of the CPU operations, a further demonstration was created where errors are introduced e.g., the data value C fed to the ALU is different from the original value stored in the IR of step 3.

In addition to completing the CPU simulation, student's understanding was assessed by undertaking an in world multiple-choice quiz. The results of the quiz, task completion, interactions with the simulation and duration in the VW are recorded in Moodle for subsequent review by the student/academic staff member. While students can undertake this process individually, the teacher can join the student in the VW to give further help and explanation if needed.

IV. Hardware Integration in the Virtual World

To integrate external hardware into VWs requires the use of a communication protocol that works within the constraints of what is offered by SL. In this instance communication and data flow is facilitated by the use of XML-RPC to send data from external hardware devices to virtual objects inside SL. This was achieved by implementing a method that connects to a dedicated SL RPC server and pushes the data through the channel created using PHP scripting with LSL. External hardware devices are controlled/accessed using a $C++$ program with PHP scripting to allow the hardware to transmit data directly to SL using winsock2 to send XML-RPC requests to the RPC handler. The XML-RPC method provided by Linden Labs relies on a RPC server for communication and passes messages to appropriate objects using a unique random channel. The sequence diagram shown in Fig. 10 highlights the 3 main steps in sending data to virtual objects.

To retrieve data sent from a virtual object, an immediate server is used to control the external hardware as the SL "Server" services the "Client". Fig. 11 illustrates the process.

1) Real-Time Wireless Sensor Demo: Using this approach Fig. 12 demonstrates the capture of temperature and light values from networked wireless sensors and shows how this data is visualised via a SL virtual representation of a physical building.

The white lights in the building show the rooms where physical lights are on, and green shows color coded temperature readings.

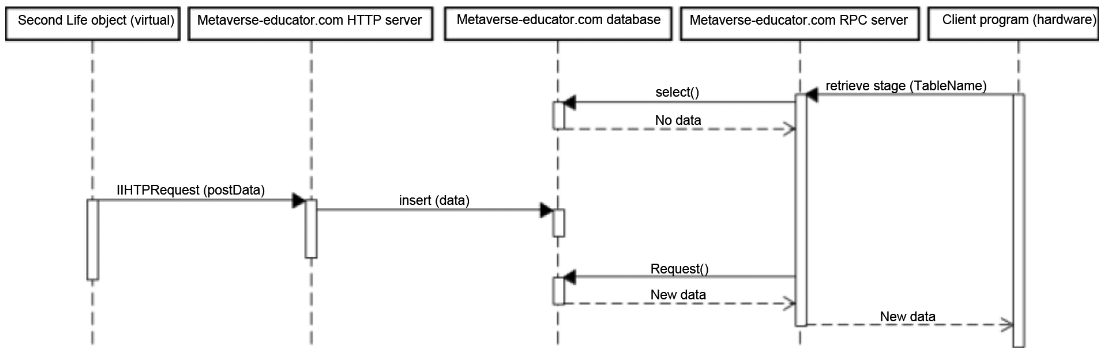

Fig. 11. Retrieving data from the virtual world.

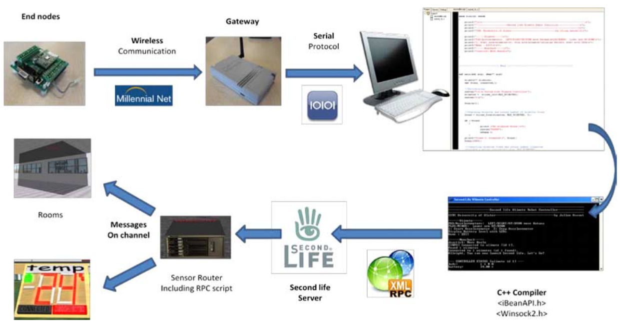

Fig. 12. External wireless sensor data captured and visualized.

Fig. 13. Remote manipulation of the robot arm using the Wiimote.

2) *Robotic ARM Demo:* By extending the approach it is possible to utilize more advanced and complex devices. Fig. 13 illustrates the use of this architecture for manipulating the movement of a virtual robotic arm inside a VW using a physical Wiimote controller.

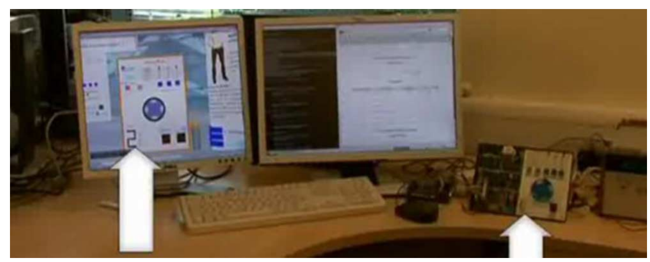

Fig. 14. Integrating a washing machine simulator into a virtual world.

User	Avatar
avatar one	JayLee Darwin

Assignment

Delete	Object Name	Task Description	Level of Completion	Date	Reset
☐	1-Open the door	Student has opened the door	Completed	August 26, 2009, 10:38 am	☐
☐	2-Close the door	Student has closed the door	Completed	August 26, 2009, 10:39 am	☐
☐	3-Green button	Student has pressed green button	Not Completed	August 26, 2009, 10:39 am	☐
☐	3-Red button	Student has pressed red button	Not Completed	August 26, 2009, 10:39 am	☐
☐	3-Yellow button	Student has pressed yellow button	Completed	August 26, 2009, 10:34 am	☐
☐	4-Accept button	Student has pressed 'accept' to start the cycle	Completed	August 26, 2009, 10:35 am	☐

Overall percentage of tasks completed:66.6%

Fig. 15. User interactions recorded into SLOODLE learning environment .

3) *Washing Machine Demo:* Fig. 14 shows a hardware washing machine emulator with its virtual representation recreated inside a VW. This demonstration allows students two-way control to program different aspects of a washing machine operation e.g., selection of wash/spin cycles. Changes in the VW actuate the same changes in the external hardware. The emulator inside the VW allows the students to collaboratively experiment with different variations of programs. Fig. 15 shows the SLOODLE tracker recording these changes/interactions which are used for subsequent review and assessment inside Moodle.

V. Game Based Learning in Virtual World's

Gamification is a term used to describe the application of video game mechanics to non-game processes in order to improve user engagement. This type of game based learning is increasingly been used in educational settings and is widely predicted to become mainstream in the next 3–5 years. To explore the potential of this approach several practical simulations were created to investigate how to represent the characteristics of electrical/electronic circuits and phenomena in the VW as game based experiences. The additional functionality afforded by VWs was also explored using three representative

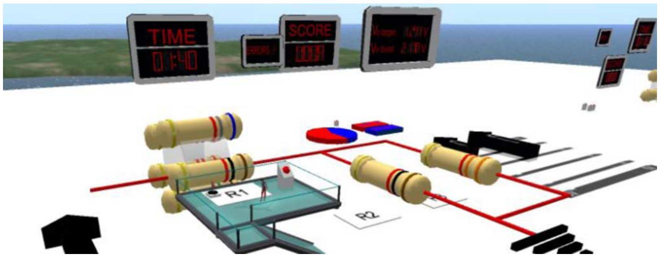

Fig. 16. Series/parallel resistor circuit.

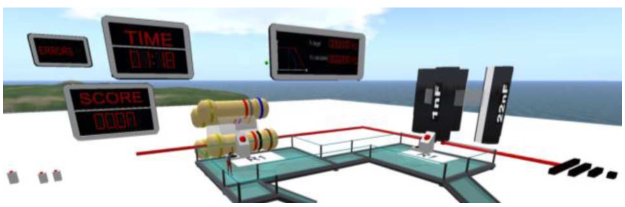

Fig. 17. RC filter circuit.

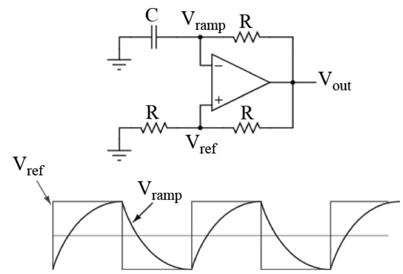

Fig. 18. Oscillator circuit with positive feedback.

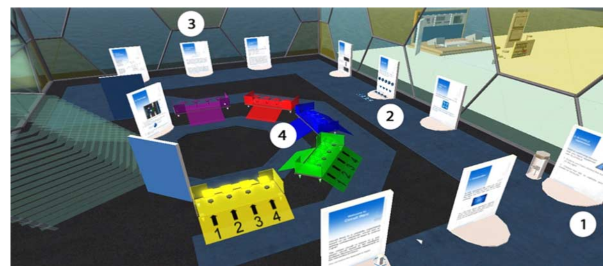

Fig. 19. Overview of learning zone.

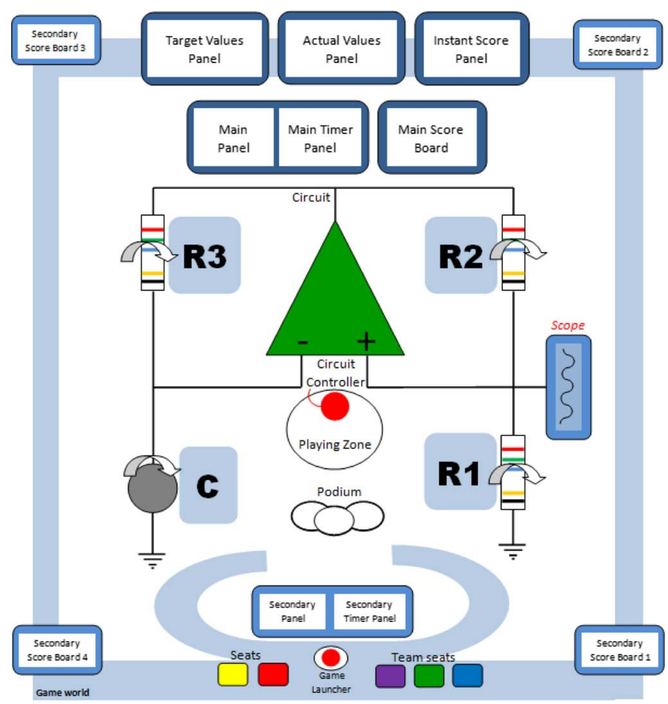

Fig. 20. Oscillator circuit realized as a game.

under-graduate (UG) examples including (1) parallel/series resistance, (2) RC circuits and (3) Oscillator circuits. Each of the examples demonstrated are supported inside the VW with complementary teaching resources to underpin and support the theory.

1) Student Learning and Assessment: Fig. 16 shows the series/parallel resistor circuit simulator where the key learning objective of the experiment was to understand parallel and series resistances. Learning was achieved by outlining exercises whereby the student would run simulations, within a given time constraint, to calculate the correct value of R1 given fixed values of R2, R3 and Vo in varying configurations. The black arrows and pie/bar charts in the simulation provided real-time feedback to the students via visualization of the relative voltage drops across the circuit as the value of R1 changed. Students are assessed on how quickly they could identify the correct value for R1 in each case by applying their theoretical knowledge practically. The feedback enabled the students to understand the circuit operation on two levels i.e., using a rule of thumb to visualize the relationship between small and large R1 values and circuit output and also on how to calculate the exact values of R1 for specific Vo values.

Similarly in the resistor/capacitor circuit in Fig. 17 the key learning objective was to understand the role of RC time constants in filters. Students learn by completing exercises where simulations are run to calculate the value of R1 and resultant cutoff frequencies. This allows the presentation of abstract circuit theory in new and highly interactive ways allowing students to experiment with different biasing setups and visualize the resulting circuit phenomenon. Students are assessed on close they match the cut off frequency to the target value, under a given time constraint, and visual feedback on performance is displayed on the score board via percentage accuracy of the circuit's output.

To further facilitate student engagement, peer-learning and assessment within the virtual environment the 'Circuit Warz' project was conceived. The overall objective of the project was to investigate if creating a compelling, engaging, immersive team based game, which facilitates collaborative and competitive group interactions to teach electrical and electronic theory and principles would increase student engagement. The secondary objective of the project was to understand the practicalities of replacing the 2-D client approach to remote laboratories with an immersive 3-D layer. The topic selected in this instance was the theory/principles of positive feedback in op-amps (Fig. 18) as it is possible to get a variety of output values from the circuit using different resistor/capacitor combinations. This level of flexibility allows the creation of a game

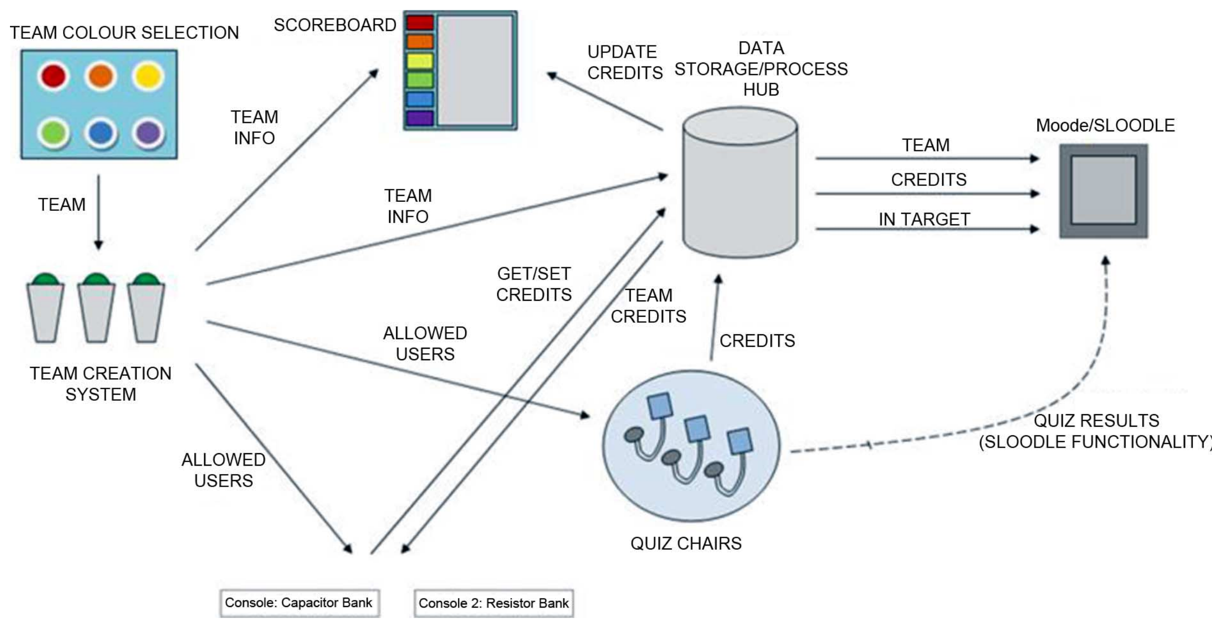

Fig. 21. Overview of user/system management functionality.

based on the generation of specific output values depending on circuit biasing configuration.

The key learning objective is to understand how to bias the oscillator circuit and the effect of different resistor/capacitor combinations on circuit output. Students learn by completing an initial quiz on circuit theory and then completing exercises in a game format where teams of students compete against other teams to bias the oscillator to achieve target peak-peak voltage and waveform periods. A learning zone was designed and divided in 4 initial sections; **registration, team creation, support material** and **quiz** (Fig. 19). Team assessments are performed against the clock where the winners are the quickest team that can successfully apply circuit theory to select individual resistor/capacitor values to achieve the pre-defined circuit output. The quiz is used to provide feedback on the theory via multiple choice questions. Feedback on the biasing assessment exercises are displayed on the score boards shown in the game implementation of Fig. 20 and provide details on how accurate their calculations were. The key novelty of this demonstration is the fact that is it linked to real hardware and the teams are working with actual physical circuits; i.e., the virtual world presentation layer allows users to interact in-world while connected to real hardware. Fig. 21 shows the user management system linked to a backend database system. Fig. 22 shows the oscillator circuit/system recreated inside the VW.

The team creation process was facilitated using a modified version of Moodle/SLOODLE where avatars can register and join teams. The management of the real hardware is done using the SLOODLE architecture to integrate the physical oscillator circuit, test instrumentation and switching matrix.

2) Managing Administration of Users and Resources: The game is controlled by the 'Central brain', a database in SLOODLE that instigates and manages the entire process, facilitating communication and interaction between the components, as shown in Fig. 23.

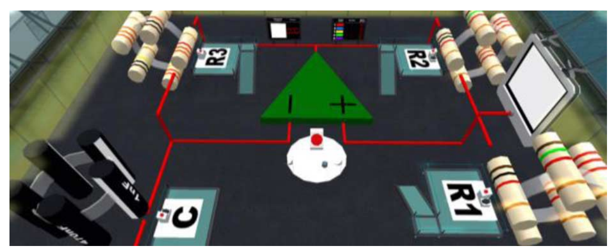

Fig. 22. Virtual circuit/arena in virtual world .

Fig. 24 shows hardware comprised of an oscillator circuit with a range of resistors and capacitors, arranged in banks which can be individually selected using the switching matrix. The test instrumentation, including an oscilloscope and power supplies are accessed and controlled using GPIB.

When the team currently playing the game selects resistor/capacitor values, the physical replica circuit is also implemented (Fig. 25) and the actual values achieved by the team are read back into the system and compared to the target values and scored (graded). The use of actual hardware causes the results to be slightly unpredictable e.g., influenced by temperature changes and circuit nuances etc. This additional feature helps the students understand that biasing circuits is not an exact science and that circuits operate within ranges e.g., resistance tolerance bands. The team with the highest overall score wins and all student interactions in the VW are recorded back into SLOODLE for future assessment and review. Fig. 26 provides an example of recorded assessment results for two teams.

3) Quiz-Based Assessment and Feedback: After teams have registered they complete the quiz and answer questions on theory, where correct answers are accumulated to enable more attempts during the circuit experimentation stage. The game starts by calling teams to the podium and providing unique

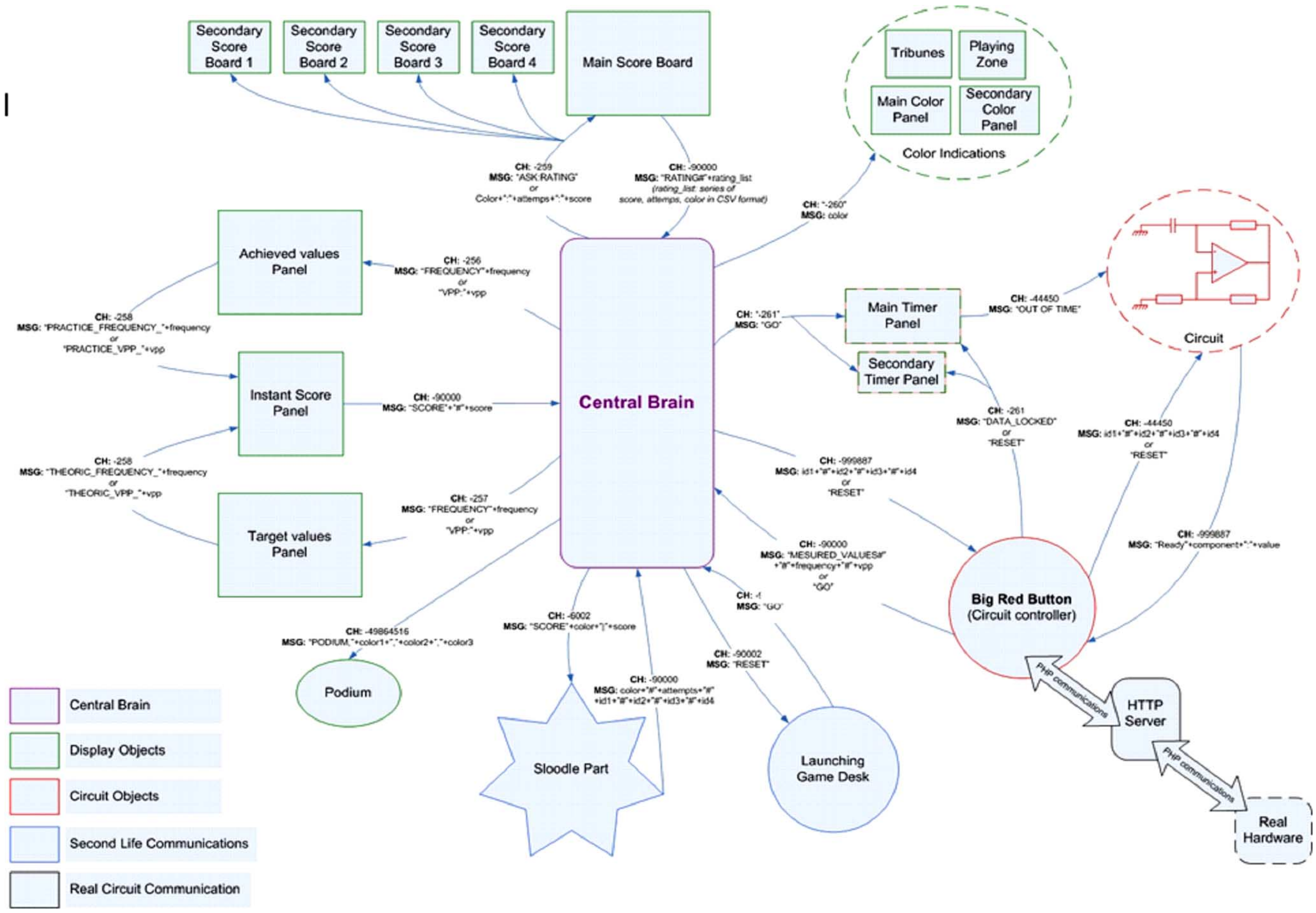

Fig. 23. Control system for Circuit Warz game.

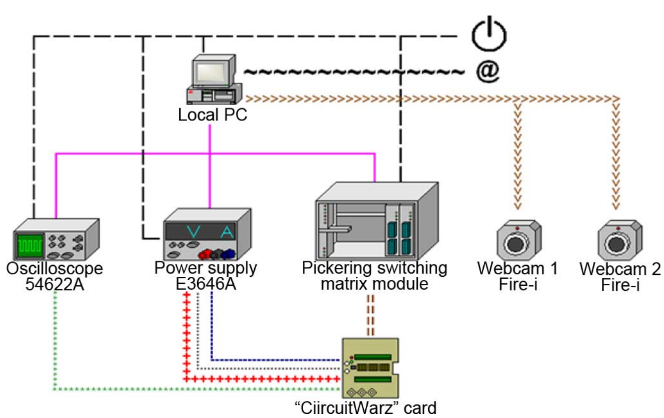

Fig. 24. Architecture of the physical hardware.

Fig. 25. Physical circuit completion.

r (Avatar)	Third Member (Avatar)	Fourth Member (Avatar)	Created in	Quiz mark (/20)	Score (/100)
	Alexi Marville (Alexi Marville)	Florent ARLINGTON (Florent Arlington)	August 27, 2010, 11:45 am	8	97
D (Fabian an)	syl20 rocket (Sylvain Swords)	Demil Mares (Demilmares Overland)	August 27, 2010, 11:49 am	7	75

Fig. 26. Team interactions recorded in Moodle/SLOODLE.

target values for Vp-p voltage and waveform period (Fig. 27). Each team is given a maximum of 3 minutes to calculate the values of resistance/capacitance and to select the resistors and capacitor in the virtual circuit, as shown in Fig. 28. When the virtual circuit is biased the red button shown in Fig. 29 is pressed.

The physical circuit is then completed and the actual values achieved by the team are read back into the system and compared to the target values and a score is provided. Scoring is based on how close the actual value achieved was compared to the target value given.

R1 (Ω)	R2 (Ω)	R3 (Ω)	C (nF)	Vpp (V)	Freq. (Hz)
1000	2200	3300	47	5.5	4695
1000	2200	3300	100	5.5	2353
1000	3300	3300	47	4.125	6390
4700	3300	3300	470	10.5	218
3300	1500	3300	22	12.312	3731

Fig. 27. Game play arena and resistor/capacitor combinations/outputs.

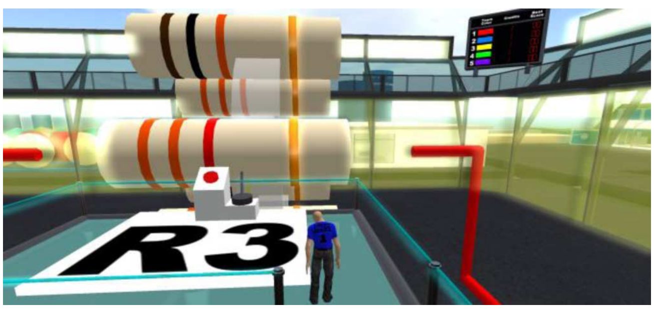

Fig. 28. Resistor value selection.

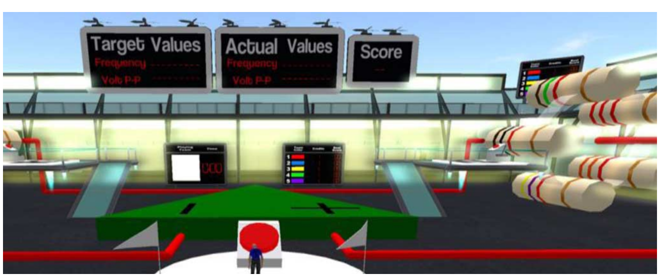

Fig. 29. Circuit completion and scoreboards.

VI. Initial Evaluation

This is a new area of research and the evaluation process at this stage mainly focused on user acceptance of these types of environments as teaching platforms from both an educator and student perspective. The evaluation looked at the age profile of the student, their familiarity with communications technologies, social networking and video gaming, the technological learning curve involved and whether the 3-D immersive environment\experience was engaging and whether it added or detracted from their experience. The overall feedback was positive. The cohort were familiar with social networking and technology in general and after a short learning curve readily accepted the game based VW as just another tool and complementary resource to add to their repertoire of learning resources with minor reservations e.g., granularity of navigation controls and interactions. In summary the students enjoyed the collaborative group aspect of the project and the ability to interact with the simulations and visualize circuit theory/operation in new and interesting ways. In addition they strongly felt that the competitive team based element of the Circuit Warz project helped reinforce the theoretical material learnt as they had to practically apply this knowledge. The academic staff involved in this stage of the evaluation, were very positive about the potential this approach had once the initial learning curve was overcome. In particular they felt the collaborative working facilities offered by the 3-D immersive environment was the most useful and warranted the extra effort required to create the content. These academic staff members would generally be classified as "early adopters" and by their very nature would be more open and responsive to embracing new technologies. Later evaluations will involve a more representative demographic of faculty academic staff.

From an overall perspective this technology is maturing rapidly and reaching the stage where it is sufficiently robust and reliable for wide scale deployment as an enhancement both to the Moodle platform and for adoption by the larger educator community. The main barriers to widespread adoption are educator awareness, the inherent learning curve, and acceptance of the possible benefits of using these environments for teaching and a willingness to explore innovative and non-standard technologies in educational practice. A careful balance is needed to ensure the use of the technology does not distract from the presentation of the subject material. In addition the underlying technology needs to mature sufficiently to a point where adding a VW simulation or game based element to teaching material is as easy as adding additional content to a VLE. At an institutional level the barriers to the widespread adoption of both technologies for teaching are significant, mainly due to technological challenges and lack of understanding of what these platforms can offer to distance education students and for now it remains a minority activity.

VII. Conclusion

This paper provided an overview on ongoing research at the University of Ulster into the use of virtual worlds/games for teaching. The Engineering Education Island project was introduced and a number of complex, highly interactive and engaging simulations described. The work was then extended to demonstrate the integration of VLEs and VWs with hardware peripherals, harnessing the relative strengths of each platform e.g., the course management features of VLEs, the immersive/highly interactive nature of VWs and the unpredictable behavior of electronic/electrical circuits. The paper demonstrated that it is possible to bring these elements together in a cohesive fashion to create a game based approach to teaching electronic/electrical engineering using a team based collaborative/competitive format. The 3-D environment successfully replaced the traditional 2-D remote laboratory interface and showed that where appropriate 3-D immersive environments could offer a new and engaging interactive way to teach engineering relate material.

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