Learning Dynamics and Control in a Virtual World

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Abstract— **Virtual worlds can support learning processes by providing visual aid that deals with the complexities of real life problems. Increasingly useful is the online use of virtual worlds and the associated technical and social interactivity. This paper describes the development of a virtual world in Second Life environment for dynamics and control learning, and outlines the use of this virtual world as a learning space in the elective course Process Systems Engineering. The outcomes based on lecturer's experience as well as on evidence from student feedback are reported and recommendations are made for the use of virtual worlds in Engineering education going forward.**

Keywords- virtual world; Second Life; learning; dynamics; control; education.

I. Introduction

The online classroom is becoming increasingly relevant in the modern connected world. For the purpose of experiential learning, i.e. laboratory and experimental based activities, many educationalists have developed online courseware targeted at experiential education. Some examples are given, for Chemistry laboratory education [1-3, 5], surgery [10], biology [10], physics [1, 2, 4], Chemical Engineering [6-8] mechanical engineering [6, 7, 9], and electrical engineering [6, 7]. The educational challenges are being met by clever utilization of information, communication and data management technologies. Most existing virtual labs take advantage of the simulation, connectivity and internet technologies but to date have the following limitations:

(1) they remain simple in nature with limited features,

(2) in almost all developments the laboratory is presented in a 2D interface,

(3) offer low usability levels, i.e. students cannot see facial expressions and get body language cues.

(4) offer low or no interactivity between the user and the virtual plant,

(5) offer low levels of scalability, i.e. limited number of students can use a particular virtual instrument at any one instant, and

(6) the simulations used are offline in many cases,

This has led to a high demand for online interactive multi-media environments that serve the goals of teaching and learning. Internet-based virtual worlds like 'Second Life' (SL) serve such a purpose very well. These environments allow students and teachers to interact with each other and with software agents through motional avatars, providing an advanced level of a social educational network service combined with general aspects of a metaverse, i.e. not limited to the physical classroom. Students can explore virtual classroom space, meet other students, socialize and participate in individual and group classroom activities. These virtual worlds have generally been well accepted by Internet users, indeed well embraced by the younger generations. Such immersive virtual spaces are flagged as highly advantageous for teaching and learning, particularly because virtual reality can help deal with the scope and complexity of real world problems where traditional classroom and laboratory settings create limitations. Educationalists are therefore adopting these to aid in delivering courses and improve aspects of their teaching and learning. This now has become an active field of research that looks into the way students learn in these environments and to measure the levels of improvement to the learning experience.

This paper (a) describes the development of a virtual world in SL for dynamics and control learning, (b) outlines the use of this virtual world as a learning space in the elective course Process Systems Engineering, (c) reports on the outcomes based on lecturer's experience as well as on evidence from student feedback and (d) makes recommendations for the use of virtual worlds in Engineering education going forward.

II. Virtual Worlds

A. Virtual Worlds and Pedagogy

There are several virtual world environments currently accessible to the public including Active Worlds [11], Second Life [12], There [13], Worlds.com [14] amongst others. A comprehensive list along with reviews of these virtual worlds can be found at [15]. While all these differ in their look and feel, they are all driven by avatars – i.e. by online manifestations of self designed to enhance interaction in virtual space [16]. While these environments have been overly used for social interaction and online gaming, educationalists have been quick to realize their value for teaching and learning, particularly because of the avatar interactions which emphasize a learner-centered education. At the same time there is the recognition of the enormous pedagogical challenges evolving due to the rise of virtual worlds. An important aim for the teacher is to initially understand learner behavior and how learning interactions occur in these up-and-coming environments.

The primary hypothesis from our pedagogical point of view is that "learning is enhanced using 3D virtual worlds". Successful implementation of a virtual laboratory is expected to enhance enormously the levels and ways experiential engineering and science learning takes place and will invite many other academics to assess their experiential teaching and learning strategies and to follow suit towards improving the effectiveness of their instruction with virtual avatar-based online classrooms and laboratories. The use of fully immersive 3D virtual spaces as environments for student interaction and learning are compatible with the following learning rationales:

- Constructivist learning: Learners participate in active problem solving with emphasis on the active role played by the learner to acquire new knowledge and concepts.
- Cooperative learning: Students learn most from their peers (and not from the teacher). Here students interact and cooperate with their peers on problem solving tasks.
- Situated learning: Learning is contextual and is embedded in a social and physical environment.
- Project-based learning: Real-life problems as learning tasks within a project setting (as described by the learning situation in Section III) enhance learning particularly when these are formed within multidisciplinary teams of students.

To begin to assess the primary hypothesis and to understand how students would benefit from learning in virtual worlds, our first objective is therefore to develop a virtual learning space to be inhabited by students learning process Dynamics and Control. The development of such a virtual classroom and associated laboratories is done in SL. This is described next.

B. Process Dynamics and Control and World Development

Arguably one of the driest and more challenging subjects to teach in the Chemical and Biomolecular Engineering curriculum is Process Dynamics and Control. The topics covered can be abstract and less motivating and typically result in students not making a connection between the fundamentals and physical implementation. Process Dynamics and Control is taught as a third year undergraduate module in the School of Chemical and Biomolecular Engineering and also inside the elective course Process Systems Engineering.

The principal aims of the Process Dynamics and Control module are to (a) understand the different dynamic behaviours exhibited by different processes in the Chemicals industry, and (b) to understand process control fundamentals to regulate the said processes. To this end, the virtual learning space was developed to provide a representation of a realistic process learning environment complete with several learning spaces (Figure 1). These include a lecture room shown in Figure 2 and collaboration/meeting rooms shown in Figure 3. A control room is built (Figure 4) to represent a realistic control room environment in a chemical manufacturing process. This is the brain centre of the chemical plant where operators monitor and control the process variables like process temperatures and flows via computer terminals. 3D visual representation of important chemical processes are built and distributed in four different laboratories positioned around the control room. Figure 5 shows a typical process (Mixing tank) in one of the four laboratories alongside an integrated slideshow. Figure 6 is from the distillation column control laboratory showing the visual capabilities possible inside the virtual world.

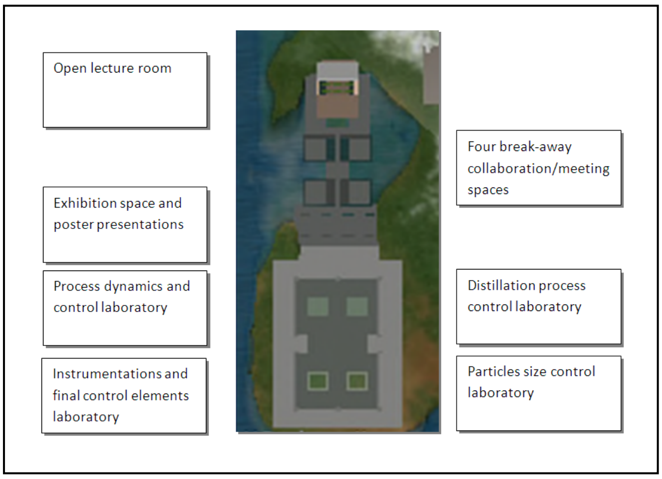

Figure 1. Aerial view of the virtual world developed for Process Dynamics and Control learning. Shown are the different learning areas including (from the top down) a lecture room, collaboration spaces, exhibition space, the four breakaway laboratories. Not visible is the control room positioned between the four laboratories and shown in Figure 2.

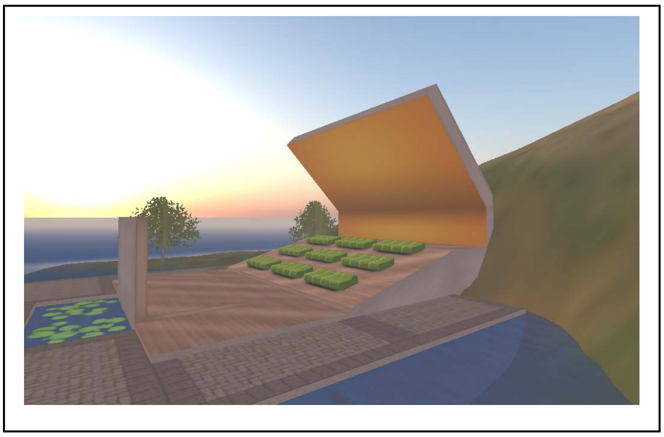

Figure 2. The virtual lecture room.

Figure 3. The virtual meeting/collaboration room.

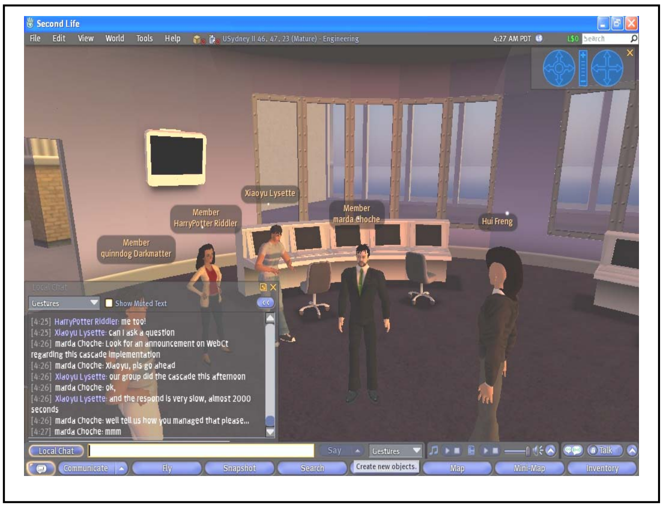

Figure 4. The virtual process control room. Student avatars can walk around, interacting with the lecturer (standing in the middle) and other students as well as with the control panels to operate virtual plants.

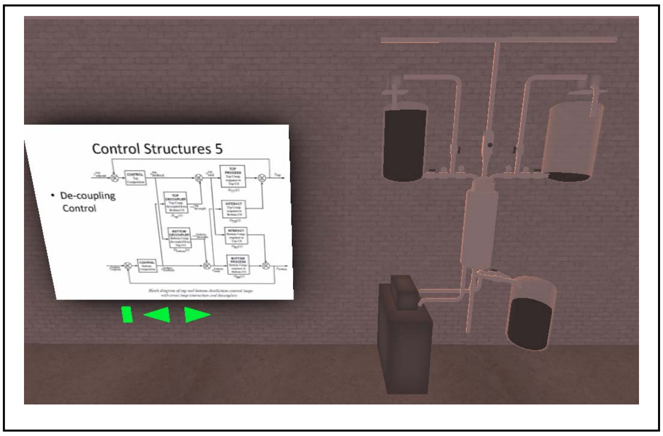

Figure 5. A virtual mixing tank (right) alongside an integrated slideshow (left).

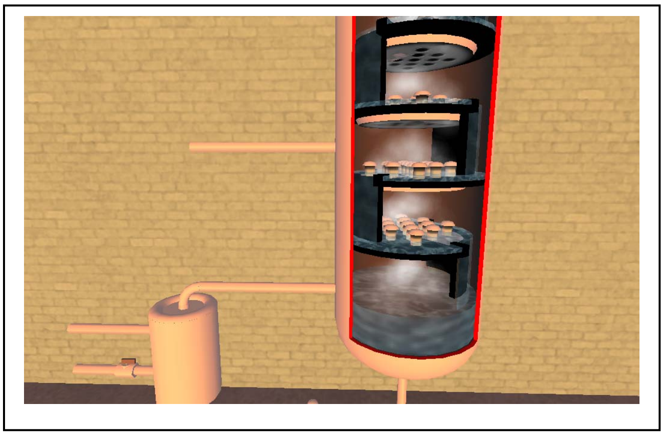

Figure 6. A virtual distillation column demonstrating visualisation capabilities inside the virtual world. Shown are the Column internals including the trays through which vapour rises contacting the liquid falling down on top of the trays.

III. LEARNING SITUATION

This section describes the use of the developed virtual world (presented in Section II) to support learning in the Process Systems Engineering unit of study delivered in the August Semester of 2009. The unit of study covered conventional as well as advanced control strategies in a project-based setting around the mixing system presented in [17] and shown in Figure 5. The project description as given to students is adapted from the "Temperature and Level Control in A Mixing Tank" problem in [18]. Students were required to work in groups to solve the project and prepare two reports – one mid-semester report and one final semester. Information on SL and the virtual space was distributed to the students early in the semester and it was left up to the students to register on the SL website and to create their avatars. While the use of SL in this unit of study was not made compulsory, it was continuously encouraged. Two SL consultation evening time slots were allocated during the week to provide students specific times for raising questions outside classroom hours. Student feedback was continuously gauged during consultation times while an end of semester questionnaire was used to obtain formal feedback.

IV. QUESTIONNAIRE AND STUDENT FEEDBACK

A. *Questionnaire*

The questionnaire was prepared aimed at gauging the extent of usage of SL in the unit of study as well as to understand what students thought of the environment. The survey questions are shown in Figure 7.

Questionnaire on using SL in Process Systems Engineering course.

Please provide some anonymous feedback on the use of SecondLife (SL) in the Unit of Study CHNG5001, in order to help us improve future course design. Thank you for taking the time to provide this feedback.

1. **How long have you spent in a country where English is a main language?** (please circle)

   a) *Less than 2 years*

   b) *More than 2 years and less than 5 years*

   c) *More than 5 years*

   d) *Most of my life*

2. **Did you use SL consultation times during this unit of study?** (please circle)

   a) *Never*

   b) *Yes, only once*

   c) *Yes, more than once but less than 5 times*

   d) *Yes, more than 5 times*

3. **If you answered (a) or (b) in question 2, what are the reasons for your answer, i.e. for not using SL consultation times?**

4. **If you answered (b), (c) or (d) to question 2, Please rate the following statement:**

Consultation in SL was beneficial for my learning (please circle):

Strongly Agree *Agree* *Neutral*

Disagree *Strongly Disagree*

5. **Would you recommend using SL in conjunction with any future courses?** Yes No

6. **What are the best aspects of using SL in this course?**

7. **What are your suggestions for improvement?**

Figure 7. Questionnaire used to evaluate usage of SL in the unit of study.

B. *Student Feedback*

There were 24 students enrolled in this unit of study and the response rate to the questionnaire was 92%. For Q2, 23% said they used SL consultation times more than once during this unit of study. For Q4, 36% (i.e. strongly agreed with agreed responses) said SL was beneficial for their learning. This shows a lower level of usage than expected and also a lower level of accepted as indicated by the low positive response of Q4. However, it is interesting that for Q5, 67% still recommended using SL in conjunction with any future courses.

Question 1 was placed in the questionnaire to understand the relationship between competency in spoken English and usage of SL. This provided an interesting result when this was viewed in relation with Q5. Of the students who said they have spent 5 years or less in a country where English is a main language, 80% recommended using SL in conjunction with any future courses, while students who said they have spent more than 5 years in a country where English is a main language, only 25% recommended using SL in conjunction with any future courses. This rather expected result showed that students who lack competency in spoken English regard SL as a valuable tool for their learning.

Several questions in the questionnaire were open-ended allowing students to express their views in writing. The main reasons for not using SL consultation times were found to be due to technical limitations with computers (video card memory requirements in particular) and networking (Broadband internet required for comfortable downloading), which could explain the low response obtained for Q4. Several positive comments were received in reply to Q6. These included:

"User feels more free to ask questions."

"We don't feel the pressure of face to face interaction, & can develop our question more focusly."

"Availability beyond class hours is always beneficial."

"I can see a future in online/virtual learning. It is very convenient and one day can be optimised to allow operation of plants at home or overseas even,…."

In reply to Q7, recommendations were made around improving technical abilities of computers as well as a number of students commenting that SL should not be used solely and should not replace the real classroom, a view shared by the author.

C. *Lecturer's Feedback and Remarks*

The author (lecturer) found the use of SL to be a pleasant experience. It provided stimulation and raised the level of interest in the project at hand. Students moved from initially seeing SL as a fun tool to later in the course seeing it as a valuable and useful consultation tool. This was evidenced by the fact that they would be logged on and waiting on several occasions for the lecturer in SL and wanting to ask questions.

The development of the laboratory came at a cost to virtual world building consultants. This was not a cheap exercise. It is envisaged that a typical laboratory with standard tools and objects would arrive at a cost of about $5,000-$10,000. Consultants fees vary depending on quality of work as well as on requirements and one could easily end up with a much larger bill. Several advanced requirements could be incorporated and are continuously developing. It is envisaged that once the SL learning curve is overcome, several ways to optimize the cost could be worked out. Teaming up with others, for instance, to build a space could become a worthwhile exercise. Having said that, one is warned not to invest heavily upfront in development. A slow approach is useful. Virtual worlds and related technologies are continuously evolving and newer environments are surely set to be released in the future which could make other environments obsolete. Will Google for instance do something about this and create its own virtual world? This would, considering Google's dominance across the Web, be set to have a disruptive effect. It is though a development to look forward to.

There are current limitations in using SL. This was restricted in this unit of study to consultation times and student-student interactions. The use of realistic process simulations, while ideal, is still limited and any useful solutions are still far off in the future. It would be of interest to interface SL virtual plants with simulation engines as well as with real plants. This would allow a higher level of interaction between the student and the virtual processes. The author is currently exploring ways to attack this problem.

There are interesting aspects of interaction with students in SL. Several students were observed to show a higher level of confidence in asking questions in SL and raising discussions. This aspect was regarded as important. Considering that SL provides voice chat as well as written chat, there is envisaged to be no disadvantage to students towards learning to speak the new language. The lecturer however would need to encourage voice chat.

Finally, it is not the intention of the author to replace the real physical laboratory with a virtual one, and this should never be any educationalist's goal. Rather, the virtual laboratory is a complementary environment that support and deepens learning. So, it is not a question of whether one should be using virtual worlds for education or not, but rather, how does one use such for education. For example, it would be very useful to have the student visit the virtual laboratory the night before the physical laboratory exercise is scheduled. Going through the virtual laboratory and the learning materials associated within it inside the virtual world provides the student with a confident approach and a leap ahead in learning prior to the lab.

V. CONCLUSIONS

This paper presented and discussed the development of a virtual world in SL for learning Process Dynamics and Control. Various aspects of the environment were discussed highlighting the features it offers from the pedagogical point of view. The successful use of SL in the unit of study Process Systems Engineering was described. Feedback from students was collected through a questionnaire which showed students to have a mixed view about the use of virtual worlds. More than 90% of students who have spent 5 years or less in an English speaking language recommended the use of SL.

The primary hypothesis that "learning is enhanced using 3D virtual worlds" could not be categorically confirmed, however, the new experience gained showed a tremendous level of possibilities for engaging and stimulating students.

Several recommendations for using virtual worlds in the educational context were presented, importantly, (1) not to invest too much and too quickly into building inside these environments due to the rapid pace the technology is moving at, and (2) to ensure that the physical laboratory is not replaced by the virtual one.

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REFERENCES

[1] http://www.innovativeeducation.com/snow/index.htm Retrieved on 20 January 2010.

[2] http://modelscience.com/ Retrieved on 20 January 2010.

[3] http://ir.chem.cmu.edu/vlab/vlab.php Retrieved on 20 January 2010.

[4] http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=140 Retrieved 20 January 2010.

[5] http://www.chm.davidson.edu/ChemistryApplets/ Retrieved on 20 January 2010.

[6] http://www.needs.org/needs/?path=/public/search/search_results/learning_resource/recommendations/index.jhtml&id=C0F00BB7-1427-4AB2-9309-5F37F2FA4F57 retrived 20 January 2010.

[7] http://www.jhu.edu/virtlab/virtlab.html Retrieved on 20 January 2010.

[8] http://reactorlab.net/ Retrieved on 20 January 2010.

[9] http://www.kfupm.edu.sa/dad/deanship/events/forums/material/dfmar2002/paper/Rahman.pdf Retrieved on 20 January 2010.

[10] http://www.hhmi.org/biointeractive/ Retrieved on 20 January 2010.

[11] Active Worlds, www.activeworlds.com, Retrieved on 11 Nov 2009.

[12] Second Life, www.secondlife.com, Retrieved on 11 Nov 2009.

[13] There, www.there.com, Retrieved on 11 Nov 2009.

[14] Worlds.com, www.worlds.com, Retrieved on 11 Nov 2009.

[15] Virtual World Review, http://www.virtualworldsreview.com, Retrieved on 11 Nov 2009.

[16] Kim, A. J. (2000). Community building on the Web. Berkeley, CA: Peachpit Press.

[17] Romagnoli J.A. and Palazoglu A. (2006), Introduction to Process Control, Taylor and Francis Group.

[18] Brosilow C. and Joseph B., (2002), Techniques of Model-based Control, Prentice Hall.