

## Educational labs in 3D virtual worlds: Improve engineer's competencies through practice labs.

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**Abstract:** The engineers are the professionals that use technology to discover and apply all available resources to change people's life. Engineers must manipulate materials, energy and information to give more comfort, security, life's expectative and environment preservation to society. To this, engineers need a solid education that have a balance among theory and practice in engineering courses. More, practical skills are requirements growing in engineering projects, requesting a new way to construction, use and access to the educational labs. This work is a PhD thesis in progress and inquires how engineering education, mainly the practical skills, can be improved by educational laboratory experience and 3D virtual world's immersion. Although not present the proposal's validation at this stage, point to good perspectives to continue research.

*Keywords:* engineering education; lab's practice; experiential learning; learning styles; virtual labs; 3D virtual world.

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### 1. INTRODUCTION

Find the balance among theory and practice always was Achilles' heel to majority of engineering courses. Perhaps because engineering is a practical profession, where hands-on is the key of work.

The first engineering schools have adopted the model of the French curriculum, that balancing theory with practice, but with the time, mainly Second World War effects, the engineering courses have focused heavily theoretical knowledge in the sciences, mathematics, chemistry and physics; and engineers were directed to solve problems based on this knowledge, but without a lot of practice in the laboratory (Feisel and Rosa, 2005).

With growing demands of market and the claims of students, the U.S. engineering universities determined quality scores to engineering courses. As Bourne at al. (2005), the Consortium SLOAN adopted five pillars of quality to measure explicit learning online education engineering and measure progress in the area: the learning effectiveness, student satisfaction, faculty satisfaction, access, and cost-effective, as showed in Figure 1.

Other modification that influenced the change of lab's idea was computer advances. In a few years smartphones and tablets has a considerable computational power; notebooks have power of processing and graphical and weightlessness and mobility; desktops and servers are upgraded often. All computer and devices are connected through broadband.

More, cloud computing, virtualization, immersion devices and controls with sensors to videogames, virtual and augmented reality can be used in the labs.

This paper has the following structure: section 2 presents the educational grounding that supports the work; section 3 describes the educational tools used: virtual labs and 3D virtual world. Section 4 shows our proposal and ends with the conclusions.

### 2. EDUCATIONAL GROUNDING

#### 2.1 *Competence = Knowledge + Skills + Attitudes*

Today, society expect for people don't have merely knowledge, but that they have competencies to use it to society's benefit. Competence is a set of elements composed of the knowledge, skills and attitudes. Such set is structured in a particular context in order to solve a problem, deal with a new situation. Thus, there is only competence established when mobilizing knowledge surpasses the 'reflective groping' available to each student and triggers consisting schemes. This allows the subject to invent original or partially original solutions for situations. These solutions may be originals from the perspective of the individual, notwithstanding that are not an overall or collective perspective (Perrenoud, 2000).

This means that isn't enough 'know', is necessary 'know do' to after 'know be'. O 'know do' is reached through knowledge's application in the practical situations. In the same direction,

Kolb (1984) proposes the model of experiential learning, where learning happens through experience. This model is based on two premises: (1) learning is the direct result of immediate experience and is found in all areas of life and all ages, from childhood to adulthood and (2) that although we are constantly learning, not all learn the same way. The learning process of each subject is unique and there emerges the development of different learning styles. This view of learning is so defined, just to emphasize the central role that the experience has in entire learning process. Kolb's model therefore works on two levels: (a) in a circle of four stages (Concrete Experience - CE, Abstract Conceptualization - AC, Reflective Observation - RO and Active Experimentation - AE) and (b) at a definition of four learning styles (diverging, assimilating, converging, and accommodating). The Figure 2 shows the Kolb's model.

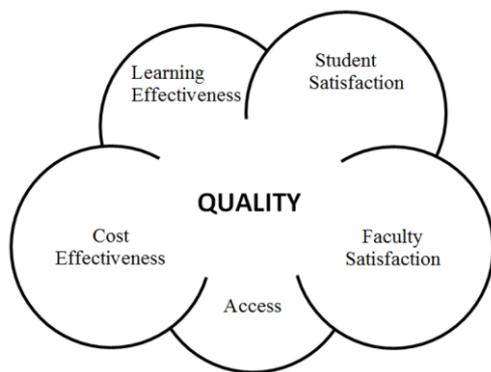


Fig. 1. The five pillars of online learning in engineering courses.

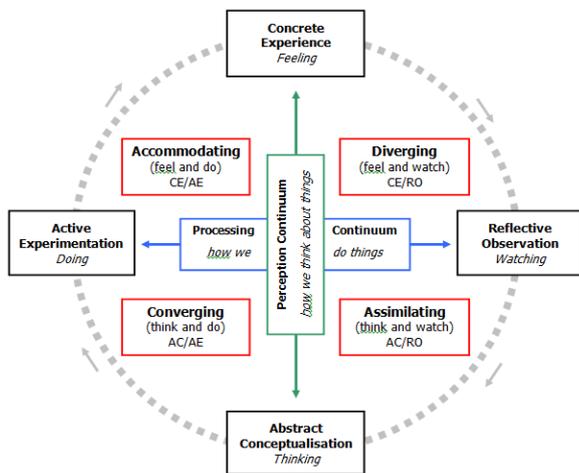


Fig. 2. The stages and styles of experiential learning.

Additionally, Jonassen et al. (2008) stated that for students to learn, they need to be engaged in a meaningful task. For meaningful learning to occur, the task the student seeks should be active, constructive, intentional, authentic and cooperative activities. Instead of testing only knowledge itself, schools should help students learn how to recognize and solve problems, understanding new phenomena,

construct mental models for these phenomena, and given a new situation, set goals and monitor their own learning.

## 2.2 Educational Laboratory

To solve a problem, engineer may need laboratory support. The labs are distinguished among three types, according Feisel and Rosa (2005) development, research and educational and described hereafter.

Engineers go to the development laboratory for two reasons: (1) they often need experimental data to guide them in designing and developing a product. The development laboratory is used to answer specific questions about nature that must be answered before a design and development process can continue and (2) is to determine if a design performs as intended. Measurements of performance are compared to specifications, and these comparisons either demonstrate compliance or indicate where, if not how, changes need to be made.

Research laboratories are used to seek broader knowledge that can be generalized and systematized, often without any specific use in mind. The output of a research laboratory is generally an addition to the overall knowledge that we have of the world, be it natural or human made.

When students, especially undergraduates, go to the laboratory, however, it is not generally to extract some data necessary for a design, to evaluate a new device, or to discover a new addition to our knowledge of the world. Each of these functions involves determining something that no one else knows or at least that is not generally available. Students, on the other hand, go to an instructional laboratory to learn something that practicing engineers are assumed to already know. That "something" needs to be better defined through carefully designed learning objectives if the considerable effort devoted to laboratories is to produce a concomitant benefit.

Educational laboratory has been complicated by the introduction of two phenomena in the past two decades: the digital computer and systems of distance learning, particularly over the Internet. The digital computer has opened new possibilities in the laboratory, including simulation, automated data acquisition, remote control of instruments, and rapid data analysis and presentation (Feisel and Rosa, 2005).

The technology through the computer and communication can help teachers to create and to support their students to understand theoretical concepts and develop practical skills. As Auer et al. (2003), the labs are basically classified concerning the location of students and type of experiment: traditional lab, local simulation, remote lab and virtual lab. To Schaf (2011), there is a clear confrontation between simulations, virtual labs and real laboratories, with local and remote user's presences. Simulations represent realistic situations and real physical experiments, although real experiments are better to learning. Virtual labs not physically exist and generally use all equipment simulated (virtual).

Real experiments are better educationally than simulations because they present characteristics often neglected by simulators - such as noise (disturbance), control limits and nonlinear effects - in addition to owning a real dynamic process and enable the use of equipment used in the industry.

### 3. EDUCATIONAL TOOLS

#### 3.1 3D Virtual Worlds

The 3D Virtual Worlds (VWs) are a persistent online representation which contains the possibility of synchronous interaction among users and between user and world, within the rules of developed space, as a navigable universe to Klastrop (2003) The VWs servers allow to users create graphical environment, that can execute isolated or in the network. Thus, the subject can be telepresent in the VW by way an avatar. The avatar is the subject's representation in the world through of the 3D graphical image. The avatar allow the user interact with the VW, giving rise a "virtual digital life" to Schlemmer et al. (2008). Additionally, Santaella (2003) defines avatar as an entirely digital cyberspace, a graphic image of variable complexity who lends his simulated life to transport surfers into the parallel worlds of cyberspace.

A good description of VWs made by Mattar (2008): "you are located, see and hear things from that point of view and then seem to be present in that environment". So far, our study indicates that this is one of the most important features of the VMs by allowing people "feel part of the world".

In Rico et al. (2011) are listed the resources to achieve educational goals in 3D virtual worlds (VWs): (1) persistence (effects of actions remain in the environment even if the user leaves); (2) access and availability 24 hours a day, seven days a week; (3) allow social interactions; (4) their 3D graphical environments would improve interaction and sense of realism; (5) is possible to see, hear and touch virtual objects as well as create, edit and manipulate them as if they were physical objects. These technologies also allow teachers and students the use of innovative learning strategies: practical training, group work, discussions, field practices, simulations, and visualizations of concepts.

The investigation of 3D virtual Worlds technology is a practice in the research group of the Centre for Interdisciplinary Studies in New Technologies in Education (CINTED, 2014) in Federal University of Rio Grande do Sul and virtual labs are one of the areas of interest (Tarouco et al, 2012), (Tarouco et al, 2013a), (Tarouco et al, 2013b), (Tibola and Tarouco, 2013).

#### 3.2 Educational Digital Labs

As described at Section 2, computers, digital systems and Internet are turning the way build laboratories. They are cheapest, available, insurance, and flexible, adjusted to each need and integrated with LMS and academic management systems. The intensity of technology use in the educational

labs depends on the discipline and the content to be experienced. To experiments of electrical concepts some resources are used. Others are used to control systems and still others to physical, mechanical, mathematical concepts.

In recent years, research about 3D virtual worlds has rising. Many researchers use the popular virtual world servers, such as Second Life (Second Life, 2013), Open Simulator (Open Simulator, 2014) and Open Wonderland (Open Wonderland Foundation, 2014). This work used Open Simulator (OpenSim) in researches.

At School of Engineering in Federal University of Rio Grande do Sul; the control, automation and robotic group (GCAR, 2014) has studied virtual labs, its integration with learning management systems and mixed reality to enhance learning of engineers and has reached good results like viewed in (Schaf and Pereira, 2007a), (Schaf and Pereira, 2007b), (Schaf et al, 2008), (Schaf and Pereira, 2009), (Schaf and Muller, 2009), (Schaf et al, 2009) (Schaf et al, 2010).

Hereafter, are presented two examples of educational labs implemented in OpenSim. The first is a physical phenomenon simulator for virtual worlds (Greis et al., 2013). In this paper beyond the system to allow the visualization of a phenomenon and display the correct answer, the simulator also seeks to assist the student to observe the phenomenon and better understand the concepts associated with it, formulate their own hypotheses and conclusions from problem situations created. In this proposal, (Greis et al., 2013) used a possible setting to be found in the real world, the collision of two cars in a toy amusement park: shock car. In this game, one person assumes control of the vehicle and attempt to deliberately collide with another vehicle. Figure 3 shows this educational lab.



Fig. 3. Lab of physical simulation (Greis et al., 2013).

Second example shows the operation of real controllers that automate processes simulated in a virtual plant (Schaf, 2011). Initially a virtual bottling plant was modelled in the OpenSim with the aid of scripts for programming the behaviour of the process. The plant consists of three workstations, each responsible for one step in the process filling bottles. Workstation 1 (filling): composed by a valve to fill the bottles, if open; a tank with a level sensor to store the liquid; and a position sensor to detect if bottle is in correct position. Workstation 2 (bottle capping): formed by a mechanical arm that capping the bottle, if turn on; and a position sensor to

detect if the bottle is in correct position. Workstation 3 (labelling): contain a label printer what print the label in the bottle, if triggered; and a position sensor to detect if the bottle is exactly in front of label printer. The student's goal is to automate the process based on information from sensors and in actuation of actuators.

To create this laboratory (Schaf, 2011) used a Hardware-in-the-Loop scenario cheap, employing the LibOpenMetaverse (Open Metaverse Foundation, 2014) to establish a hyper connection with a real controller. An Arduino board, model 2009 and basic electrical components were utilized like controller. Arduino board is cheap and easy to programming with a language near C language. This language is compiled to machine language and performed in to ATmega328 microcontroller (Arduino, 2014). Figure 4 shows this lab.

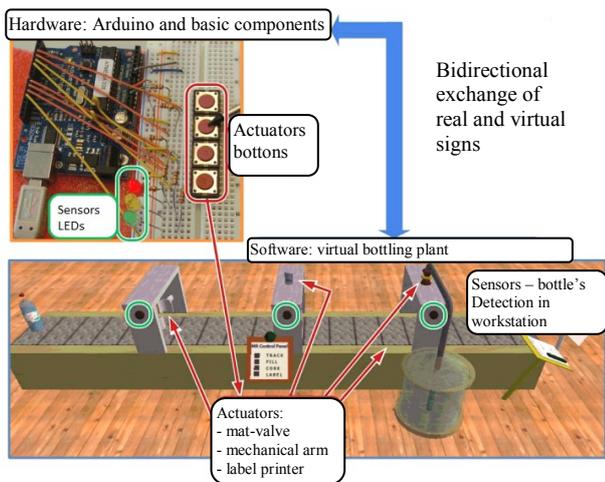


Fig. 4. Virtual bottling plant (Schaf, 2011).

#### 4. THE PROPOSED ARCHITECTURE

In 3D Virtual Worlds, the fundamental element is the primitive or prim. Prim is the basic building block (made up of polygons). A prim has a name, description, material, and a basic shape (box, sphere, cylinder, torus, etc.). To 'give life' to prims is necessary a programming language. This language is LSL (Linden Scripting Language). This is the language all scripts in Second Life (and others 3D virtual world servers) are written in. A script in Second Life (or OpenSim) is a set of instructions that can be placed inside any primitive object in the world, but not inside an avatar (Second Life, 2013).

When we join objects and LSL code we have action. Through of LSL codes the objects can have the behaviour that we wish (provided it respect with the rules of the world server). Thus, the objects can be programmed to act when: (1) receive a "touch" (basic way of avatar's interaction with objects); (2) detect presence of the avatar to defined distance; (3) receive a message from other objects; (4) the user enter text in the chat box and send it to objects via communication channels. In these cases, communication channels are used to communicate within world, but they are used to communicate with systems, devices or programs outside world (Tibola and Tarouco, 2013).

An important point to development of educational labs in 3D Virtual Worlds is its capability to interoperate with others systems. A way to interchange data between OpenSim and others systems is HTTP protocol. In our researches were developed bidirectional communications of OpenSim server with databases, and with WWW servers (running CGI and/or Web Services). Figure 5 shows this experience. Other communication experience happens with XML-RPC. To (Second Life, 2013), XML-RPC is a standard for sending Procedure Calls to remote systems. It sends XML data over HTTP that remote system then handles. LSL receives XML-RPC requests and passes them to the prim specified. It may not establish this connection, but it may reply and keep two-way communication with that server. Figure 6 shows the XML-RPC communication with that server. In (Tibola and Tarouco, 2013) several samples of external communication are described.

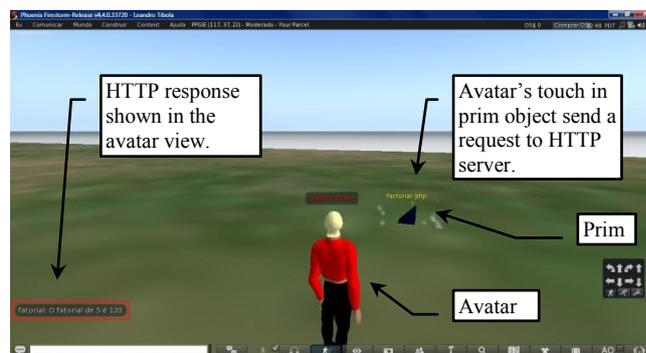


Fig. 5. Communication of OpenSim with WEB server over HTTP.

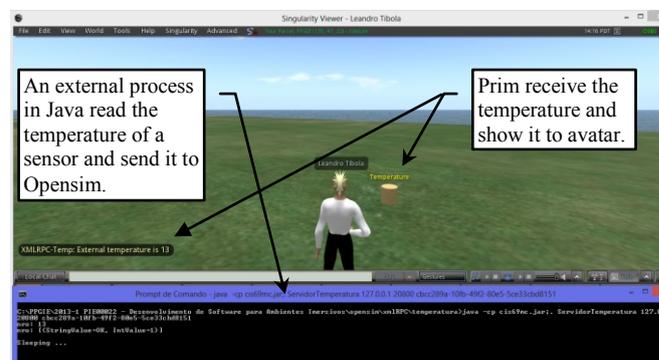


Fig. 6. XML-RPC communication with OpenSim.

Beyond these resources, OpenSim allow create the Non Player Character (NPC). According (Chaney, 2014) a NPC is a character that is controlled by the game master in table top role-playing games. In video games and other scenarios with character representations an NPC is generally controlled by a program, not by a human. As (Second Life, 2013) an NPC is a "robot" which is controlled by a machine, rather than by a human. This can have various uses, such as to perform group invitations, perform as a NPC in a roleplaying game, as mannequin in a shop. Figure 7 shows avatar and NPC communication.

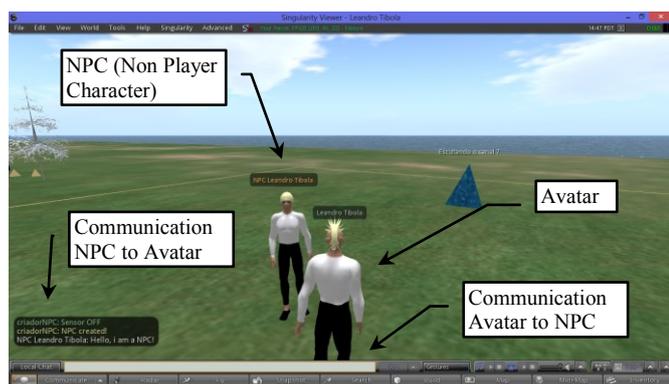


Fig. 7. A way of communication among NPC and Avatar.

Based in cited works and our researches to date, we propose creating an educational lab to support engineering course, like described hereafter: (1) studying the experiential learning, learning styles and the meaningful learning, identifying what pedagogical concepts are necessary to design an educational lab; (2) select a domain of engineering course to modelling their contents to practical classes at lab; (3) create learning objects (LOs) to selected domain; (4) join LOs to form an educational lab; (5) identify a programming technique of multi-agent systems (MAS) to apply into the NPC; (6) design intelligent tutors (through NPCs) based in same pedagogical concepts that LOs to guide the student; (7) make available the educational lab to students; (8) seek evidences of engagement and interaction of students in the activities in educational lab.

The pedagogical theory needed this proposal can be obtained by means of scientific papers, books and professional interviews, identifying the practical applications these theories and how they can be transferred to 3D Virtual World.

To develop this proposal, prims and LSL code will build the learning objects to the specific content of an engineering domain and the student will make the experiences to prove the theory and concepts viewed at class. With the communication resources, will possible interchanging data with physical or virtual experiments, and with learning management systems (LMS). The student will do practice activities structured and based in pedagogical theory, with learning objects projected to his needs, accessing data and interacting with external experiences. These possibilities result in a richest experience.

But, make the lab available isn't enough. Students will need support to achieve the pedagogical goals. As this lab kind is available 7 X 24 hours, the teacher will not always be present. To avoid this situation, a NPC will guide student while he/she accomplish the lab's experience. NPC will be designed to follow an educational theory, which will allow greater consistence in its guidelines. The communication between NPC and student may be made by chat box (OpenSim have sound resource, but we need more study to use them). Thus, student will enter her doubt in the chat box and NPC will answer it. Of course that NPC will understand a number of questions, derived of MAS's programming. The idea is induce the NPC with basic support and add know in the time. The MAS technique will allow define the

behaviour's set to the NPC. Thus, more behaviour can be adding to improve NPC's guidance.

More, NPC will explore all communication resources. NPC can consult LMS, databases or external systems by HTTP protocol. Too, 'real' world can be accessed through XML-RPC (appliances, rooms, buildings, and all things with sensors - the Internet of Things). So, NPC could search information about the student in LMS or send the result of the lab's activities to it. NPC could write the student's doubts to a database or send his performance to cell phone, e-mail or social net. It could send a message to professor's cell phone when the doubt is out of his knowledge base. Many others functions are possible to empower the NPC.

Once this work is developed within research group GCAR, is natural some similarities between individual works. This research also follow the general outlines as the works of (Schaf et al., 2010) and (Schaf, 2011); but differently, do a deeper approach for guidance in lab activities by intelligent tutoring (Non Player Character - NPC in virtual worlds) from a pedagogical theory and strategy to learning and teaching. Also intend to define a MAS framework, compatible with virtual world, to allow NPC 'learn' with the user and enlarge their knowledge database. Like this, through communication protocols will be stored data about student's activities in the lab, enabling recognize evidences of engagement and interaction from analysis this data. Thus, with measures of engagement and interaction may evaluate some aspects of learning and teaching process.

## 5. CONCLUSIONS

Although is a work in progress, the discoveries aforementioned bring up clues that seem be a good direction. From them, we realized that our proposal match the works described: (a) is WWW ready, (b) only need an Opensim viewer, (c) exchange data with external systems and 'real' world. More, our proposal can contribute with science adding: (1) expand 3D Virtual World's connection with 'real' world; (2) apply an educational theory to strongly support the student; (3) design and develop intelligent tutors student-driven, based in educational theory; (4) seek evidences of engagement and interaction in student activities in virtual practice lab. As future work the development of the learning objects and prototype NPCs based in intelligent tutoring systems, which will form the lab in 3D Virtual World.

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