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A Learning Evaluation for an Immersive Virtual Laboratory for Technical Training applied into a Welding Workshop

Francisco Torres
Universidad Autónoma de Nuevo León, MEXICO

Leticia A. Neira Tovar
Universidad Autónoma de Nuevo León, MEXICO

Marta Sylvia del Rio
Universidad de Monterrey, MEXICO

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ABSTRACT

This study aims to explore the results of welding virtual training performance, designed using a learning model based on cognitive and usability techniques, applying an immersive concept focused on person attention. Moreover, it also intended to demonstrate that exits a moderating effect of performance improvement when the user experience is taken as a feed-back for the student. The results can provide important information to increase the operator performance during the training of welding complex machines to reduce accidents and waste of test material.

Keywords: Immersion, Training, Usability, Virtual Reality, Welding

RATIONALE AND PURPOSE

A common problem at the welding workshop in technical schools is to show the students how to use the material in a safety way and to optimize the basic resources. This is often due to space and a limited budget for maintenance and equipment.

There are many research papers claiming that thanks to information technologies can improve learning efficiency using tools such as virtual laboratories, platforms educational administration tools and multimedia format which are focused mainly strengthen academic content. These technologies have been validate through the performance of students in different research works. Some research based on a robotic technology, (Erden & Tomiyama, 2009).

Correspondence: Francisco Torres, *Universidad Autónoma de Nuevo León, Av.Alfonso Reyes s/n, San Nicolás NL, Mex. 66450,*
franciscot@gmail.com

State of the literature

- Currently there are different research and technologies that allow the link between the use of virtual reality tools and activities of the manufacturing industry (Ong & Nee, 2004).A group of researchers from the University of Iowa (Stone, McLaurin, Zhong, & Watts, 2013) conducted a study in which they designed a virtual course using virtual reality tools, which was integrated into the learning program welding, not found significant differences between different educational formats. Another work published 2015 IEEE Virtual Reality (VR), a study of Onew360, which is tool formatted virtual reality that functions as coach welding was exposed, this meets the standards of interaction, quality of graphics, interactivity and sense of immersion (Benkai, Qiang & Liang, 2015).In the study "Virtual Reality-based Training System for Metal Active Gas Welding" argument is presented that virtual reality can help increase the quality in welding processes (Hwa, Zahari, Hui & Chee, 2014).Graph theory is actively used in various areas biochemistry, engineering and computer sciences; that give hints about its use in problem solving.
- In 2012, Nielsen proposed five components to define usability: learnability, efficiency, memorization, error handling and satisfaction. This measure how easily can be for a user complete a task for each design (Mendoza, Alvarez, Mendoza, Acosta, & Muñoz, 2015).

Contribution of this paper to the literature

- Although there are different investigations concerning the use of virtual reality tools for welding processes it has not been investigated from a usability perspective and level of attention of the person. In order that a user can take full advantage of virtual reality application, it assumed the existence of a problem of interaction where we evaluate two main components: The application will be evaluated through a methodology heuristics and second one is the user attention level, which will be evaluated by an eye-tracking tool that is based on usability techniques.

Within a constructivists learning model with a multi perspective approach it is necessary for students to have an environment where they can perform technological experiments. Working in a workshop lab creates an interactive experience that encourages development and provides practical knowledge. Some cognitive processes arise through interaction; these play an important role in semantic construction.

Usability within a platform refers to the interaction between the software and the users. (Nielsen J. (1994). This means, the software will be easy to learn and navigate, allowing the user explore its potential through an attractive interface and operations. The software can be used efficiently, reducing errors and increase user satisfaction, among others.

This article focuses on studying the design and construction of a virtual workshop lab through human interaction, to solve a problem using a virtual welding machine. The student reads from his book Practice of welding, which outlines a task to perform. During the activity time, the student can interact with the safe use of welding material. Even when following instructions, the student may overlook some details, which could lead to accidents or laboratory instruments damage. The result of the research includes an analysis of the construction of a virtual lab and the experience of users throughout their educational experience.

One of the most important aspects at the development of graphical interfaces, is to consider the principles of usability, the success of the interaction depends on an oriented design focus to the user's responsibilities and context, (Clark R.C. & Mayer R.C, 2011).

THEORETICAL FOUNDATION

New technologies are every day, used to support the development of educational software, with the aim of improving the user experience. The use of a new technology does not guarantee a better user experience, it is necessary to conduct a thorough evaluation to find areas of opportunity in the development of graphical interfaces,(Pablo Moreno-Ger & Javier Torrente,2012).To measure the effectiveness of a virtual learning environment is necessary to assess whether this has all elements.

Fitt's Law refers to the time required to reach a target press depends on a logarithmic relationship between its surface and the distance. (Scott MacKenzie, 1992). In the case of a virtual interface you can create an enriched environment that allows the user to generate additional support to find faster your goal.

In this research, it develop a 3D graphic interface to representing the atmosphere of a welding shop with the aim of finding a relationship between usability principles and data, defects occur intentionally by using an eye-tracker with the objective of evaluating the adaptability of the user in a learning environment in 3D.

In this paper, we use aspects of immersion, this term has been extensively studied and used by many researchers, not simply by Information Technology or virtual reality but additionally by areas such as education, the media and even literature (Huang, Kinshuk & Spector 2012).

We can define the immersion process as the process in which the subject focuses attention on an alternate reality there is a disconnect with the outside attention building a parallel world (Hwa Choi, Dailey-Hebert, & Simmons-Estes 2016; Freyermuth, 2015, Šorgo, & Kocijančič, 2012)

According to studies conducted by Bjork and Holopainen (2004), immersion can be categorized into: Sensory-motor (Sensory-motoric Immersion), cognitive (Cognitive Immersion), emotional (emotional Immersion) and spatial (Spatial Immersion). This is described in the **Table 1.**

Table 1. Immersive categories

Sensory-motric	In virtual reality scenarios you are able to perform control of space and time
Cognitive	The subject through logical reasoning is able to solve the problems of interaction with the scenario
Emotional	The subject through the interaction can make a link by affectivity
Spatial	The subject is able to assimilate the virtual world just as real. This type immersion is commonly used for research in video games and virtual reality

Eye tracking, a tool to evaluate the visual experience, has become an increasingly common tool in identifying problems in immersion. Sweeney (2008) suggests that there is a connection between studies of eye tracking and immersion he argues that occurs in the interaction of the subject with 3d stage thanks to the attention this allows the user to generate spatial immersion (Childs & Peachey, 2013).

RESEARCH QUESTIONS

Based on theoretical foundation, it is interesting to ask the following research questions, which will addressed from the perspective of human-computer interaction:

1- Are there differences between men and women in the eye tracking metrics Adaptation Time, Execution Time, Interaction Time.?

2- Is it possible to evaluate the usability of a virtual reality system with the Nielsen methodology?

METHOD

Based on their experience with virtual training environments, the authors used at this work a four steps methodology, described below:

Step 1: Security measures

Class starts when the student enters to the classroom and the instructor explain the process in order that they can understand the vocabulary used, can identify the virtual reality tools and increasing the understandable of each participant. For example, Turn on the PC, Open the program, and connect the Oculus and the Kinect.

The practice of welding machine introduces the user to take all safety equipment to perform practice safely and efficiently.

Once the student is in the room dedicated for the class, with the equipment in place the class can start, **Fig. 2.** The teacher gives introduction of the scheduled issue proceeds to give a theoretical explanation, then begins the practice in the virtual laboratory the group will form groups in order to participate in the class with feedbacks and support.

Once the student is interacting with the application, the first stage is to take the protective equipment and wear it. Then, should lead to the worktable, once equipped with mask, gloves and have taken placed 2 tubes welded on the table. This is the key to get access to Stage 2.

Figure1. Security measures

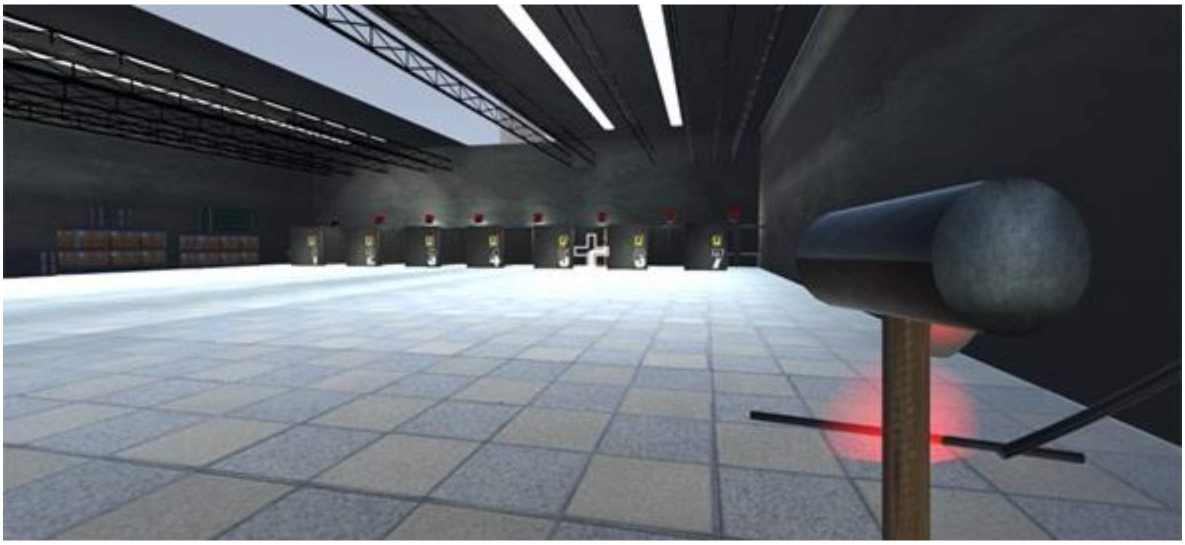

Figure2. Start instructions

Step2: Practice

This step consist to weld 2 tubes, to turn the welding machine is necessary to have the mask on, then you can move the welding gun through the tubes until a progress of 100%, the end is taken, the damage look and you can give a rating time / damage that occurred to the product, **Fig 3**.

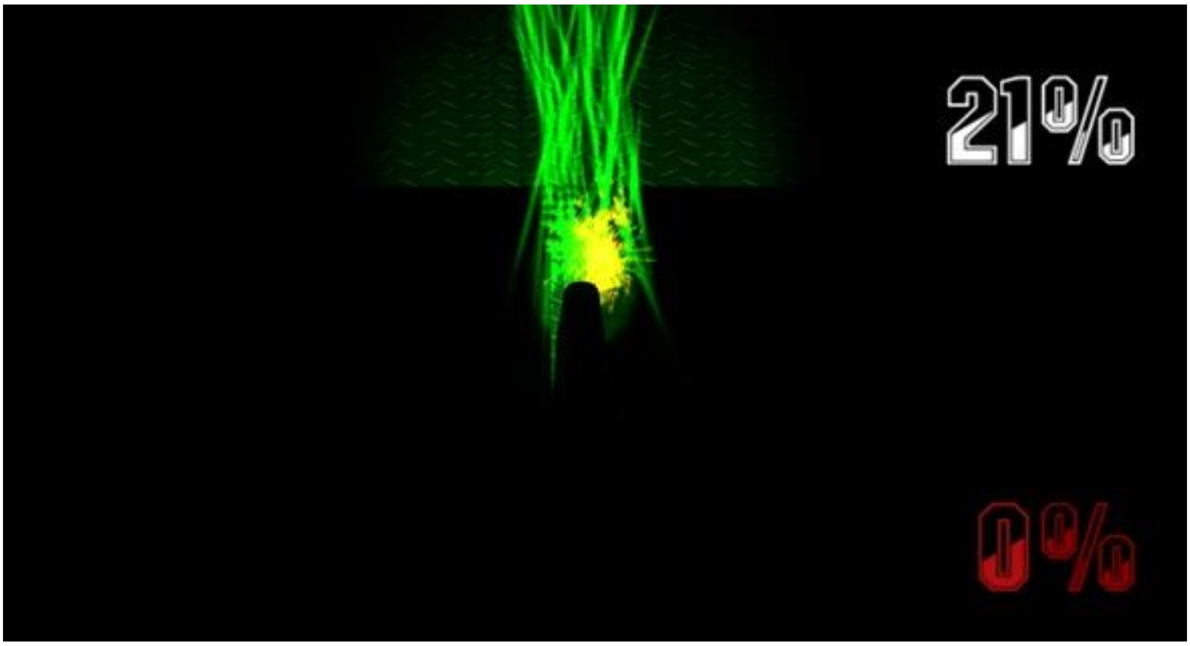

Figure 3. Rating Time

Step 3.Eyetracking Study

To identify and evaluate the usability problems that could be present at this virtual scenario was used an eye tracking study. Eye tracking has become increasingly used in identifying usability problems. Ehmke researched the correlation between eye tracking metrics and the usability problems. (Ehmke C. &Wilson S. 2007) .In this paper we study the problems presented by the software and the fixations points of each of the interface screens.

The first usability issue found concerns the cursor shown in many of the screens. The task designed for **figure 4** asked the student where should he begin, and the heat map indicates people were sidetracked by the cursor. Thus, it must be removed when it is not required for performing tasks. **Table 2** shows the fixation points of the area of interest (AOI), in this case the cursor, versus the rest of the image.

Table2. Fixation points on AOI and non-AOIs

Not on AOI	AOI_1

0,118	0,125

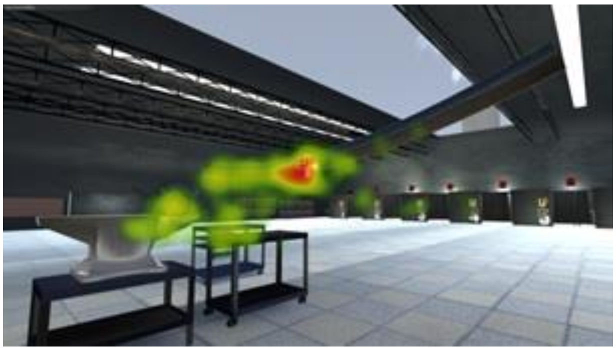

Figure 4. Heat map of main screen

Another usability problem detected was the size of the menu functions. According to Fitt's Law (Scott MacKenzie, 1992), the most important functions must be presented in larger areas. In this task, students were asked to select and wear a welding mask. In the menu designed the cursor, text, buttons, gloves and hammer present larger fixation points than the actual mask. The Menu needed to be enlarged.

Figure 5a. AOI for the menu options

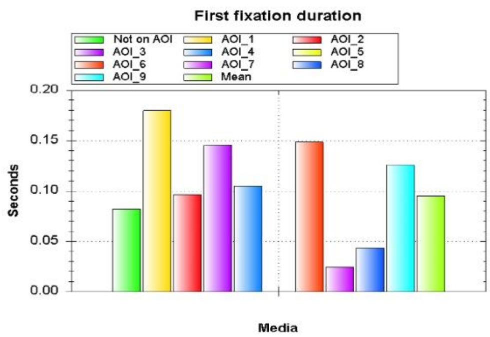

Figure 5b. Fixation points for AOIs

After welding, students need to evaluate their performance. Percentages where their accuracy or errors are displayed, were not seen by 50% of users. The minimum acceptable percentage is 85%, so these numbers must be made more visible.

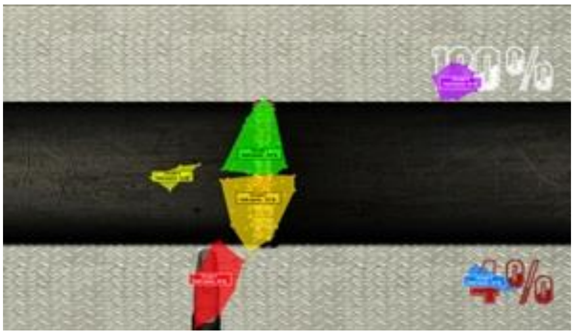

Figure 6. Cluster diagram of wielding results

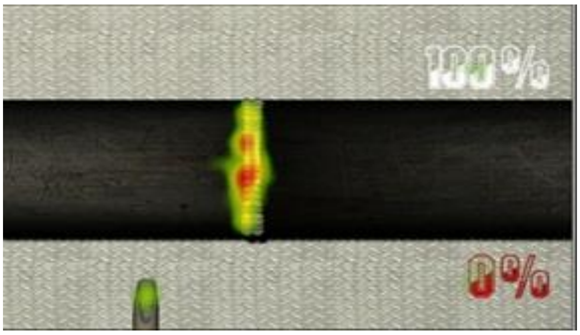

Figure 7. Heat map of wielding results

Test done after the final modifications show that most usability problems were corrected.

Step 4: Testing

The sample target that was chosen for this study were engineering students because of their experience in the use of information systems in web mode for tracking information. None of the participants had experience with the welding process or the team for the simulation. Thus, the sample was for convenience. The group consisted of 30 students aged between 18 and 22 years, where approximately 45% were women and the rest men.

RESEARCH DESIGN

For this research two measurements were made with respect to the user experience in virtual laboratories, the first involved eye tracker device and the second consist in a questionnaire that explores the 10 points raised by Nielsen mentioned in the previous section through saturation responses and factor analysis. The instrument was performed three times, which allowed all its items were discriminatory. Responses were Likert scale show where you could qualify as follows:

[5 =] Not usability problem.

[4 =] minor problem: there needs to be fixed unless you have time to spare.

[3 =] minor problem: fix is not very important.

[2 =] serious problem: it is important to fix it.

[1 =] Disaster: It is mandatory to fix

In the different applications it explained the 10 categories and the vocabulary used in the instrument in order to be comprehensible to participants.

Equipment requirements

- The classroom should have a minimum space of 25 square meters and an optimum of 50 square meters.
- Empty space of 3 x 3 square meters.
- It must have an HD projector.
- Augmented reality glasses oculus rift.
- Kinect 2.0 device.
- Computers with enough hardware to run 3d renders.

Figure 8. Virtual reality equipment.

RESULTS

A usability test was applied after the participants interacted with the platform; it was conducted through a questionnaire that evaluates the 10 Nielsen's dimensions of usability. The instrument reached a Cronbach Alpha coefficient of .648. The test result threw the results shown in the **Table 3.**

Table 3. Nielsen´s Dimensions, mean and standard deviation

Dimension	Mean	Std. Devitation	Mean	Std. Devitation	Mean	Std. Devitation
Visibility	3,5714	0,75593	4,0000	0,8165	3,7778	0,80064
Similitude	2,5714	0,64621	2,2308	0,92681	2,4074	0,79707
User Control	2,2857	0,72627	3,3077	1,25064	2,7778	1,1209
Consistency and standards	2,9286	0,61573	3,1538	0,80064	3,037	0,7061
Error prevention	3,0000	0,78446	2,4615	1,19829	2,7407	1,02254
Preference	2,2857	0,46881	2,7692	0,92681	2,5185	0,75296
Flexibility	2,3571	0,8419	2,7692	1,01274	2,5556	0,9337
Aesthetic and minimalist design	2,8571	0,53452	2,7692	0,83205	2,8148	0,68146
User help	3,5714	1,15787	3,3846	0,76795	3,4815	0,91548
Documentation	3,4286	0,64621	3,3077	0,48038	3,3704	0,56488

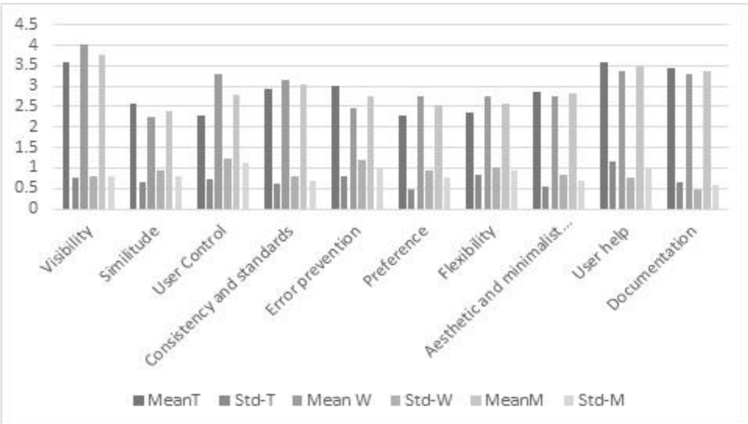

Figure 9. Nielsen´s Dimensions Chart.

As an additional indicator of time following measurements were made: Execution Time, represent the total time; Adaptation Time; is the time in which user learned how to use the control and finally the Interaction time; is the time that user took to complete the task. (**Table 4**).

Table 4. Total Interaction Time

		Mean	Std Deviation
Women	Execution Time	802557	1,38278
	Interaction Time	14,1429	2,62699
	Adaptation Time	5,8571	2,24832
Men	Execution Time	7,9231	2,2532
	Interaction Time	14,6923	2,35884
	Adaptation Time	6,7692	2,89119
Total	Execution Time	8,1111	1,82574
	Interaction Time	14,4074	2,46918
	Adaptation Time	6,2963	2,56927

Table 5. Plot Glaze results

		Mean	Std. Deviation
Women	Not_on_AOITime_to_first_fixation	0,0319	0,09446
	Not_on_AOIFixation_Length	3,8419	0,19918
	Not_on_AOIFirst_fixation_duration	0,1804	0,0829
	Not_on_AOIFixation_Count	11,6429	2,37316
Men	Not_on_AOITime_to_first_fixation	0,0128	0,01701
	Not_on_AOIFixation_Length	3,8699	0,25905
	Not_on_AOIFirst_fixation_duration	0,2342	0,07502
	Not_on_AOIFixation_Count	11,2308	2,91987
Total	Not_on_AOITime_to_first_fixation	0,0227	0,06848
	Not_on_AOIFixation_Length	3,8554	0,22585
	Not_on_AOIFirst_fixation_duration	0,2063	0,08235
	Not_on_AOIFixation_Count	11,4444	2,6067

DISCUSSION

If we look at the results section, there are no major differences between men and women at the metrics. Viewing a virtual working environment can have different scopes format from the technique used to represent it. Different number of indicators belonging to visualize intended environment, can be seen in the views used.

One of the most important aspects in the development of interfaces is to consider usability principles in the success of the interaction we can see that the two highest values were the visibility and user help. Although the design took into account the principles of usability, it was observed that the meanings of usability are different for participants.

For example, in the concept user interfaces help to marks, additional notes and percentage indicators was added. Users indicated that they expect an auditory aid that gives clues during the process. Regarding the design you can observe there is a lack of distracting in color contrast.

CONCLUSIONS

For future research could be planned test welding experts with the aim of creating data that allow comparison between different metrics. While the virtual environment allows immersion a very similar physical setting, is also working on a device with generating torch features enabling give a more optimal experience and introduce levels of difficulty, focuses to improve the welder posture.

Thanks to the results observed in student behavior, could be consider the future of this research, to be extend to share experiences in remote group using the oculus cinema technology and to use a different kind of welding scenarios.

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