Reporting and Analyzing Student Behavior in 3D Virtual Worlds

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Abstract—**Virtual Worlds are open 3D environments capable of simulating a variety of educational practices, thus reducing risks and costs with physical laboratories. However, its freedom characteristic can cause dispersion and make it difficult to navigate and focus. Aiming at improving user navigation, this paper analyzes a Heads Up Display (HUD) solution that keeps sensing the locations visited by the user, and presents it in the form of a "heat map". The main contribution has two sides: 1) a reporting system is presented, which allows teachers to easily keep up with students' behavior in the environment; 2) an analysis of experimental data has been performed, focusing on the extent and intensity of content observation, with the purpose of presenting the potential of the HUD to act as a guidance tool in educational Virtual Worlds.**

Keywords-virtual worlds; heads up display; student interaction.

I. INTRODUCTION

This paper is an extended version of [1], which proposed the use of Heads Up Display (HUD) device working as a heat map, to create a context-aware Virtual World (VW), coming to the conclusion that it helped on students' navigation. The HUD could be attached to any user's screen by touch, and it would keep dynamically inferring its context, changing colors according to the locations visited and the frequency (or duration) of visitation.

VW are 3D open environments where users, represented by their own avatars, can move around, meet and interact with other avatars [2]. This technology is capable of simulating whole environments, thus greatly decreasing costs and risks of conducting experiments in physical laboratories [3].

Also, according to Englund [4], it enables to move away from traditional classroom learning and to design activities with an emphasis not on "learning about", but with focus on "learning by being" or "learning by doing". Mastrokoukou and Fokides [5] highlight that although the development of these environments is quite a lengthy process, long term benefits of its use may arise, since it can be reused several times.

Chow [6] explains that a VW is characterized by being more exploratory, active and participatory, rather than centralized in listening and absorbing information. Multiusers are encouraged to navigate freely through different locations within the environment, to develop their own learning processes, according to their own demand [7].

Due to the great diversity of didactic materials that can be inserted in VW, such as texts, images, videos and presentation slides, different spaces or rooms can be created, separated by, for example, subject or type/category of content. Simsek and Can [8] assert that giving students the freedom to choose the type of learning material to explore, makes them more active individuals in their learning process.

As the ones who spend more time inside it tend to interact more with educational objects [9], it is desirable for the user to spend long times navigating the VW. Studies have described that the total number of visits to a learning object may indicate student interest [10].

However, these characteristics of discovery-based environments, which offer the greatest potential to promote learning, at the same time represent the biggest challenge: the complexity of the learning experience [11]. According to Mayer [12], environments designed to make users discover

materials completely on their own are harder to use. Gütl [13] discovered that if users spend too much time learning to use a complex interface they might leave the environment.

This leads to several educational implications, as engagement hindrance or demotivation, as users may be distracted by numerous functions and simulated scenes in the VW, disturbing their attention from the learning contents [3].

For example, Ijaz, Bogdanovych and Trescak [14] found, in an unsupervised experiment, that participants did not properly explore the VW: important areas were left unexplored. Also, some students faced technical issues and did not fully achieve the learning objective; in consequence, scored low in the exam. In their study, Griol, Molina and Callejas [15] found that the amount of options and tools available in the VW had a negative effect in some students, who felt disoriented. They suggest this happened especially to players of video games, as they are used to follow a script, with predefined outcomes.

This way, Christensen, Maraunchak and Stefanelli [16] suggest that the educational use of VW must be carefully articulated and organized by the teacher. Csikszentmihalyi [17] emphasizes that activities stimulate more flow if they embody certain rules and clearly state what the users should do.

Moreover, for immersive learning environments to act as it is expected, with students having great flexibility while faced with numerous learning opportunities, intelligent real-time support and guidance is required [14]. This means that, in accordance with Tüzün and Özdinç [18], being informed about the objects and locations in the environment plays a key role in getting to know about other paths. Baydas et al. [19] exemplified how reflective guidance, directive signs, symbols, footprints and notice boards within the VW can be helpful in achieving the learning goals, getting some positive results.

However, one of the most complicated aspects inside VW is precisely automatic scaffolding or guidance, since it is very large and flexible [18]. As stressed by Soliman and Guetl [20], it is not unusual to see the lack of autonomous support in VW, and learners find themselves alone with no guidance.

The usual approach to provide automatic guidance on VW is concentrated on virtual agents. According to Johnson, Rickel and Lester [21] animated agents that can serve as guides are an important instructional aid, so students won't become disoriented and lost in virtual reality environments. Xie and Luo [22] identified that students performed better and in less time because they could find the destinations quickly with the help of virtual agents. Also, they felt more satisfied.

In the last decades, ubiquitous computing techniques have been used aimed at improving student performance, and consequently, beneficiating institutional cost effectiveness [23]. In line with this trend, and as an alternative from the virtual agents' scenario, several researches have benefited from the use of HUD device capabilities, available to implement in most of the VW platforms, as OpenSimulator and Second Life, to personalize and dynamize VW in different ways.

Extending the work of [1], in the current research we intend to: a) establish a way to enable teachers to easily extract reports of student's behavior in the environment, in order to help monitoring educational activities; and b) analyze differently the records from the experiment previously performed, to verify if the HUD can influence in the extent and in the intensity of didactic content observation in the environment. Thus, we will try to answer the following main research question: *how is it possible to (1) report and (2) analyze student behavior inside Virtual Worlds?* We will discuss on how these two aspects can be useful for student assessment and pedagogical improvements in educational VW.

The article is organized as follows: Section II presents the related work; Section III explains the research method; Section IV presents the developed report system; Section V shows the analysis performed with the data, discussing results found; ending with Section VI, which presents the conclusions and future research.

II. RELATED WORK

In this section, we present some examples of how HUD and heat map devices have been used towards optimizing user experience.

Using Second Life platform, Shah, Bell and Sukthankar [24] implemented a recommendation system that suggests places to visit, personalized with the user's destination preferences. To acquire data on users' travel patterns, they developed a custom tracker object using the Linden Scripting Language (LSL), which periodically prompts the user to enter information describing and evaluating its current location. The HUD could be worn on the right or left side of the screen, and it monitor the avatar current location (x, y, z coordinates).

In the study of Keelan et al. [25] each participant was given a HUD that allowed them to indicate up to eight emotional states throughout the Second Life visitation, four positive and four negative. The goal was to identify and analyze which aspects invoked emotional responses, and what kinds of information were considered trustworthy or untrustworthy by the users.

One of the promising VW applications that seem to demand such a device is the visit of virtual museums. In this field, Sookhanaphibarn and Thawonmas [26] emphasize that personalization can play a key role for increasing the number of return visitors. They mention the idea of using HUD to show personalized recommendations in VW, like to what has already been implemented for physical museums, but with the advantages of requesting simple implementation and no additional cost.

Likewise, Ward and Sonneborn [27] implemented a HUD that provides subtitles of dialogue in many languages, including English, French, German, Spanish, Italian, and

Portuguese. Also, the HUD records the avatar's position so users can know where they are in the build and receive audio, pictorial and textual information about what they are seeing on their visit.

In the field of displaying or highlighting locations to situate the student, the Virtual Learning Environment (VLE) MOODLE in more recent versions (2.7 onwards) has a plugin that implements the "heat map" concept to help user navigation, using a color scheme (yellow, orange and red) to represent the "heating". The heat map highlights areas as well as components that highly attracted students' attention by counting the number of clicks.

Rakoczi [28] developed a similar system, but tracking the student's eye movements to identify areas "more looked", that is, which captured more attention, as shown in Figure 1.

Figure 1. Heat map of MOODLE's calendar [28].

Similarly to the studies presented, Krassmann et al. [1] showed the initial results of the development and application of a context-aware HUD that works as a heat map, "heating" (changing colors) as the locations in the VW are visited more often, allowing the user to be aware of his/her own navigation behavior. The authors explored how this device could help on improving engagement and interaction time, getting some good results.

In this extended version, we present the development of a system that allows teachers to extract reports from user's behavior in the Virtual World, enabling to see patterns of students' access in a simple and intuitive way, facilitating monitoring and assessment, without the need for the teacher to be in person observing the activity. Also, we analyze some of the data gathered from the experiment performed in [1], using statistical techniques to investigate new hypothesis, as the impact of the HUD in the extent and intensity of content observation, and in face of the difficulty level of accessing locations in the virtual environment.

III. MATERIALS AND METHOD

The research is an exploratory quasi-experimental study, with a convenient sample of individuals who had a minimum

level of computer skills. A region in the Virtual World from AVATAR Project [29] (an acronym in Portuguese that means Virtual Learning Environment and Remote Academic Work) was used. This project intends to investigate, test and promote the training and the use of virtual laboratories in immersive environments, using the open-source OpenSimulator platform. A set of regions are implemented in this VW, within different subjects as Physics, Electricity, Chemistry, among others.

Students enrolled in courses at the authors' university and colleagues that work on the project were invited to participate in the experiment, which took place on the university facilities. Singularity [30] and Firestorm [31] viewers were used to enter the VW, being those free softwares capable of rendering the 3D graphical environment appropriately.

To explain more in detail the method of research, we have created subsections regarding the VW development, the heat map HUD implementation and the experiment design and execution.

A. The Virtual World

Two virtual laboratories, in one region from AVATAR Project, were used: Waves and Wireless Networks, which are introduced on Krassmann et al. [32]. According to the authors, in these environments students from Secondary or Technical education have the opportunity to visualize the practical side of some abstract concepts that are part of their daily life, as the propagation of radio waves and Wi-Fi communication.

To improve the organization of content and provide a clear distribution, these two teaching contents were divide into 12 topics, distributed along 12 specific locations in the two laboratories, which are presented in Table I.

TABLE I. LOCATIONS AND TOPICS DISTRIBUTION

Number	Content topic/subject
1	Wave Characteristics
2	AM and FM Radio Waves
3	Wave Phenomena
4	Electromagnetic Spectrum
5	Introduction to Wireless Networks I
6	Introduction to Wireless Networks II
7	Wireless Networks Topologies
8	Infrared and Bluetooth
9	Range of Wireless Networks I
10	Range of Wireless Networks II
11	Range of Wireless Networks III
12	Material interference in propagating wireless networks

In each of the 12 locations, different didactic materials such as videos, presentation slides, images, texts, animated digital media, audios, web pages embedded in QR (Quick Response) code and simulations were implemented, according to the location subject. Each one was identified as to their type through luminous plaques and with short

instructions displayed on the bottom, seeking to provide an intuitive and independent navigation for users.

Figure 2 presents a screenshot of the environment entrance. It can be seen that a control panel was placed at the beginning of the path, containing buttons that give the user introductory information, for example, on how to move around, use the didactic materials and what is expected in this visitation. Also, there's a green button where the user can attach itself the HUD. In this case, the user have already pushed the button and the HUD is on the right side the screen.

Figure 2. Waves and Wireless Networks Laboratories entrance.

To help on student guidance, Figure 3 shows plaques simulating wooden material with arrows pointing the directions to each location. The aim of this signalization was to ensure that users without the HUD could also navigate the environment and visit all the locations available.

Figure 3. Plaques with arrows pointing the directions to each location.

B. The heat map HUD

The HUD is composed of a numerical map of the environment. It can be attached by the user by touching one time on the corresponding button, and it goes to its top right screen. It works sensing the places visited, recording into a database and retrieving this information in real time.

The HUD is composed of 12 prims (primitives – 3D object unit) that are linked. Each prim has its own texture that identifies the number and the topic of one location, and its own scripts to change its color from white to red, "heating" according to the frequency of access or time elapsed on visitation. To do this, the classification presented in Table II was idealized and adopted.

TABLE II. HEAT MAP CLASSIFICATION ON HUD

Color	Tag	Frequency	Time elapsed
Yellow	Weak	Second time	2 minutes
Orange	Medium	Third time	3 minutes
Red	Strong	Fourth time	4 minutes

In this sense, if the user has remained at one of the 12 locations for at least two minutes, according to our classification, it is assumed he/she is visiting this location for the second time, so the prim on the HUD that represents this location turns yellow; after three minutes it turns orange, and after four minutes it turns red. The sensor checks every five seconds for the presence of an avatar and consults in the database if this specific user has already visited the place, registering it only after every minute (60 seconds), in an incremental way. The prim also has the ability, by touching it, to tele transport users to the respective location.

Figure 4 shows the heat map following the user's avatar at two different locations in the VW. It can be seen, for example, that this user has visited Location 5 very often (red), but Location 3 lacks visiting, as it is still white (top screen). It also shows that Location 8 is now changed from yellow to red (bottom screen). So it can be concluded that this user got back to that location twice more and/or has spent more two minutes in the same spot (from yellow – 2 minutes; to red – 4 minutes).

Figure 4. HUD following the student in two different locations.

The identification of locations inside the VW were signalized with circles on the floor, with sensors programmed to identify avatars presence in a radius of eight meters. Figure 5 shows a screenshot of Location 4 "Electromagnetic Spectrum", with the gray circle on the floor identifying it ("L4").
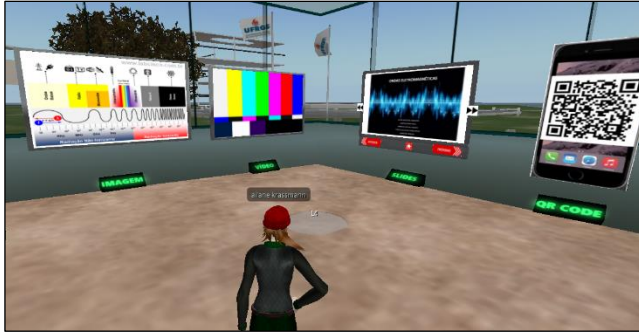
Figure 5. Screenshot of Location 4 "Electromagnetic Spectrum".

Besides LSL programming language, OpenSimulator Scripting Language (OSSL) was used to program the HUD. To capture data from each user in real time, the sensors collect data and send it through HTTP requests. All this procedures are managed by a WAMP system (Windows, Apache, MySQL, PHP).

More specifically, the function *llSensor* was used to create an invisible monitoring field, defining the area of the sweep (eight meters). This sensor is activated every 60 seconds, through the use of *llSetTimerEvent(60)* function, whose call is carried out by the instruction. In this way, the sensor checks if there are users in its coverage range every 60 seconds. If so, the avatar name is verified and stored, along with the information about the current location.

The script which performs this sensing operation in the VW environment works in the following way (written in pseudocode).

```
1.  Set the time: llSetTimerEvent(60)

2.  When time reaches, activate sensor:
    llSensor("", NULL_KEY, AGENT, 8, PI)

3.  When sensor activates, search for avatar name:
    avatar_name = llDetectedName(x) + avatar_name

4.  Once avatar name is captured, gather the data:
    string hud =
    avatar_name+location_id+location_name+time

5.  Pass the data to PHP file:
    llHTTPRequest("http://server/heatmap.php?dados
    _user="+hud, [HTTP_METHOD,"GET"],"")

6.  Get the answer from server:
    http_response(key request_id, integer status,
    list metadata, string hud)
```

As shown in the pseudocode presented, the information is sent through the function *llHTTPRequest*. The function *HTTP_METHOD* "GET" is the one which enables the PHP file in the server to receive the data. The file receives it and "explodes" it in an array, separating location id, location name and time the user remained in that location. The names of each user that were inside the sensor area at the moment of data collection are separated and organized. Another function works registering time records in which this

occurred. After all these treatments, data are ready to be sent to MySQL database, where they are stored.

Data are stored in the "heat map" table of the database, as follows: a) user's name; b) name and ID of the location visited; c) time user remained in that location (60, 120, 180 or 240 seconds); d) the current heat map status for the user at that location (white, yellow, orange or red); e) time records. When visiting a location for the first time, a new complete record is inserted in this table, so time and current heat map status attributes are subsequently updated, according to an incremental analysis of time elapsed.

Immediately after this procedure, the *avatar_name* attribute has to be cleaned, so it can be received again and compared in the table. The *http_response* then brings the answer, which is passed through the channel 225 (selected by us) to update the HUD, if necessary.

This process can occur simultaneously for several users, receiving all interactions occurred from the sensors inserted inside the environment, allowing the sensing of multiple users in different locations, without competition problems.

C. The experiment

Data from an experiment performed in Krassmann et al. [1] is analyzed. As described by the authors, on the occasion 16 individuals, divided into control and experimental groups, were informed about the experiment goals, the voluntary aspect of their participation and the complete confidentiality of any data gathered about them. Each one received an individual login to access the 3D environment. They were instructed to freely and intuitively navigate in the VW, without any pedagogical path or visitation time previously defined. The purpose of this orientation was to provide them with freedom to interact in places they considered appropriate, visiting the desired materials and remaining in each location as long as they were interested.

Immediately after the session, that lasted for an average of approximately 33 minutes, a questionnaire was administered, containing demographic questions and items regarding the navigation in the environment, including the impressions about the heat map (HUD) for the experimental group. The main findings are presented in the original paper [1]. In this extended version we focus on creating a reporting system and analyzing student interaction in a more profound way, which corresponds to the two next sections.

IV. REPORTING STUDENT INTERACTION

As mentioned by Balderas et al. [33], VWs developed using open-source software — such as OpenSimulator — allow developers and teachers to access student logs and retrieve valuable information on learners' in-world behavior and interaction. This possibility, explored in this research, is important not only in terms of assessment: it also facilitates the identification of learner profiles and VW behavior patterns, which can help improving the environment, as it allows the accomplishment of different types of actions to assist the students during their interaction [27].

Duncan, Miller and Jiang [34] corroborates that having a good understanding of the user's in-world behavior can help on improving the educational use. They suggest that, as students virtually participate, it may be hard for the teachers to monitor the educational process, being difficult to tell whether the students are actually learning or playing in the VLE.

However, a high degree of dependence on the teacher or his/her constant intervention in the activity is also undesirable. Ijaz, Bogdanovych and Trescak [14] discovered that it decreases interactivity and immersion of participants: users became less engaged in the experience and were keen to finish it quickly.

In order to improve and facilitate student monitoring and evaluation, by the pedagogic point of view and in an autonomous way, a reporting web-system was developed. Its objective is to facilitate the process of analysis of student's interactions inside the 3D VLE without the need of the teacher assistance. The system was basically developed with the PHP programming language and the connection to the MySQL database, with the previously described "heat map" table, which stores all user interactions received from the HUD.

With the data of each user, it is possible to identify which places were visited in the environment, since in these places sensors are triggered by the presence of a user and record this information in the database. In this sense, based on the data collected from students interactions in the two laboratories (12 locations), we have implemented six different types of reports, described as follows.

1.   Student Activity Report: the data of a specific user, selected by the teacher, are presented for an individual assessment, showing locations the student visited, how long he/she remained on each one, and the tags related to each time. An example is presented in Figure 6.

2.   Activity Report by Location: in this report all interactions occurring in a specific location are extracted, allowing the teacher to see an overview of places that have been visited the most, and, on the other hand, which need to be more stimulated to visitation. For instance, it might be a warning for the teacher that a specific location lacks attractiveness. Figure 7 shows a clipping of an example of this report, showing all user presence captured in Location 8 "Infrared and Bluetooth".

3.   Activity Report by Time: the teacher has the possibility to investigate, in this report, the interaction that occurred in different intervals of time, covering all locations and students. For example, it can show all the places and users with a 180 seconds tag (visited three times or for three minutes). It can be useful for the teacher, for instance, to immediately verify places more accessed (time = 240 seconds) and, on the other hand, places that were never visited (time = 0 seconds).

Student Activity Report

Avatar Name	Room/Location	Time	Tag	Time records
aliane krassmann	AM and FM Radio Waves	120	Weak	2017-09-26 16:16:51
aliane krassmann	Wave Characteristics	180	Medium	2017-09-26 16:23:52
aliane krassmann	Electromagnetic Spectrum	240	Strong	2017-09-27 08:43:51
aliane krassmann	Introduction to Wireless Networks I	180	Medium	2017-09-27 08:44:47
aliane krassmann	Wireless Networks Topologies	180	Medium	2017-09-27 08:44:55
aliane krassmann	Infrared and Bluetooth	180	Medium	2017-09-27 08:46:04
aliane krassmann	Material interference in propagating wireless networks	180	Medium	2017-09-27 08:49:17

Figure 6. Example of User Activity Report (Report 1).

Activity Report by Location

Avatar Name	Room/Location	Time	Tag	Time records
renan luigi	Infrared and Bluetooth	180	Medium	2018-01-12 16:49:08
renan bortoluzzi	Infrared and Bluetooth	180	Medium	2018-01-12 16:49:08
user user_9	Infrared and Bluetooth	120	Weak	2017-09-28 10:21:34
user user_8	Infrared and Bluetooth	180	Medium	2017-09-28 09:40:09
user user_8	Infrared and Bluetooth	120	Weak	2017-09-29 17:33:16
user user_7	Infrared and Bluetooth	120	Weak	2017-09-27 14:34:38
user user_5	Infrared and Bluetooth	180	Medium	2017-09-27 08:49:04

Figure 7. Example of Activity Report by Location (Report 2).

4.   Activity Report by Color: similar to the previous report, in this case it is possible to perform the analysis of student interaction according to the color tags defined in the heat map (white, yellow, orange and red), covering all

locations. In this case, teacher can use the color tag to identify places more and less visited.

5.   **Detailed Activity Report:** seeking to provide the teacher with more details of each student behavior, this report presents the summarized data of a selected user, as it can be seen in the clipping of example presented in Figure 8. It shows the total number of visits in each location, how long it was the total visit duration on each place, and the number of heat map tags received for each location. In this sense, this report allows the teacher to see where a specific student have been in the VLE and for how long, allowing, for example, to evaluate him/her.

Detailed Activity Report

Select a name ▼   Select an interval ▼

[Search]

L1 - Wave Characteristics

Total of visits: 4

Total of seconds in the location: 240

Total of Weak tags: 0

Total of Mediums tags: 0

Total of Strong tags: 1

L2 - AM and FM Radio Waves

Total of visits: 2

Total of seconds in the location: 120

Total of Weak tags: 1

Total of Mediums tags: 0

Total of Strong tags: 0

Figure 8. Example of Detailed Activity Report (Report 5).

6.   **Full Report:** this report aims to provide the teacher with all the information stored in the database in a summarized way. It enables to have a panorama of the whole class interaction in the VW, and to do filtered searches in a diversity of ways, seeking to analyze more specific data. It also allows, for instance, the teacher to evaluate the activity, to analyze if all the locations projected for learning were used (or useful).

Each report is ordered decreasingly chronologically, and it can be generated in three different periods: weekly, monthly and complete, by selecting an option in field "select an interval". In addition, all the reports have the option of being exported in Portable Document Format (PDF), or can be downloaded in the form of customizable worksheets, so the teachers have the freedom to manipulate and store the reports according to their preference or need.

Through this web system, teachers can perform activities with a group of students in the Virtual World without the need of being present to observe the procedure all the time, consequently influencing in the student freedom and feelings of immersion [14]. Also, this way, giving proper instructions, students can access the environment from home.

The data are easily available on the internet, through any device. It can be used to assist the teacher on the self-evaluation, the analysis and/or the assessment of the whole class or each student individually, at any time and from anywhere.

V. ANALYZING STUDENT INTERACTION

This section aims to complement the analysis presented in Krassmann et al. [1], investigating data from the experiment performed by the authors in a more thorough way.

The original article did some inferences based mostly on students' self-report, that is, based on subjective opinions about the VW, which implicates on individuals personal aspects, as personality or mood. Focusing on making a more objective analysis, aiming to identify patterns from the experimental group (using the HUD), and compare it with the control group (that did not use the HUD), data from students interactions in the Virtual World were analyzed by the light of statistical inference tests, using the software Minitab version 17.

A sample composed of 10 individuals, being six from the experimental group and four from the control group was selected. This low sample is because not all participants' records were properly registered in the database, due to adjustments done in the scripts by the researchers during the experiments period.

The following new research questions (RQ) have driven this data analysis:

• RQ1 - Is there any impact of the HUD in the extension of content observation inside the Virtual World?

• RQ2 - Is there any impact of the HUD in the intensity of content observation inside the Virtual World?

• RQ3 - Is there any impact of the HUD in the difficulty level to find locations inside the Virtual World, regarding the extension and the intensity of content observation?

To investigate RQ1, it was created a formula that identifies the degree of student experimentation of all locations, which we named ECO (Extension of Content Observation), since each location relates to a topic content, calculated using (1).

$$\frac{\sum_{i=1}^{n} Quantity\, of\, Accessed\, Locations\, by\, student' i'}{Quantity\, of\, Available\, Locations \times n} \quad (1)$$

n=total of assessed students

As result, the ECO of control group had an average of 0.75, while the value obtained for the experimental group was 0.66. It means that, overall, students from control group accessed 75% of locations at least once, and the students from experimental group accessed a bit less, about 65%.

Thus, we can answers RQ1 with a yes, there is some impact of the HUD in the extension of content observation in the VW, but not as we expected: the users with the heat map device visited a lower number of locations. In other words, higher level of content observation (locations) was covered by control group. Some inferences trying to explain this fact are made on RQ2 explanation. However, t-tests performed to compare ECO of both groups could not reject the null hypothesis of equality, with p=0.57 at confidence level of 95%.

RQ2 is concerned with the intensity of access of locations, considering to the heat map classification (Table II). It is here called ICO (Intensity of Content Observation), and is calculated according to (2).

$$\frac{\sum_{i=1}^{n} Quantity\,of\,4th\,time\,Access(\;)Location\,Visit'\imath\imath}{Quantity\,of\,Available\,Locations \times n} \quad (2)$$

n= total of assessed students

For this measure, instead of considering all locations visited by users, it was considered only locations that were accessed at least four times (or 4 minutes – strong/red tag).

As result, the ICO for the control group was 0.25 and for the experimental group 0.28. This answers RQ2, showing that yes, there is an impact, although small, of the HUD in the intensity of content observation in the VW: individuals from experimental group visited locations with a bit higher frequency. However, the null hypothesis that the ICO of both groups is equal has not been rejected, with p=0.82.

The results for RQ2 indicate a positive impact of the heat map in the Virtual World activity and complement RQ1. It shows that, although students using the heat map visited less locations, they visited it with more intensity (with more frequency or stayed for more time). Among the reasons for this fact, we speculate that maybe they felt more compelled to achieve the heat map completeness (turn red locations on the HUD).

One of the potential advantages of using this concept of heat map in VW is to highlight areas that have not been explored yet by the users, especially places that may be more difficult to find in the 3D virtual space, in consequence to the environment design. We investigated this usefulness in RQ3.

First, we assigned a difficulty level of access for each location in the Virtual World, considering researchers' experience while observing student difficulty to find them when navigating the 3D VLE. So, it was created the classification displayed in Table III.

TABLE III.   DIFFICULTY CLASSIFICATION OF LOCATIONS

Location number	Difficulty to find
1, 4, 5, 6, 7, 8, 10	Easy
2, 3, 9	Moderate
11, 12	Hard

Easy locations are the ones considered more visible, with no obstacles to reach it. Moderate locations are a little hidden, requiring students to go inside rooms and/or to climb stairs. Hard locations are the ones in different buildings or in more hidden places, as behind walls, for example. Figure 9 shows an example of a moderate to find location, as the user had to climb the stair on the right side of the screen to be able to see the wireless propagation simulation (Location 9).

Figure 9. Screenshot of Location 9 "Range of Wireless Networks I".

Following this classification, ECO and ICO metrics were calculated for each level of difficulty and compared between control and experimental groups. The results are shown in Table IV.

TABLE IV.   ECO AND ICO ACCORDING TO ACCESS DIFFICULTY

Location classification	ECO		ICO	
	Control	Exp.	Control	Exp.
Easy	0.78	0.76	0.46	0.40
Moderate	0.83	0.61	0.08	0.22
Hard	0.50	0.41	0.00	0.17

This result indicates a clear impact of the heat map, especially in ICO metric for the "moderate" and "hard" location classifications, since the difference of values between groups are bigger (0.14 and 0.17). The data show that students from experimental group accessed for much more time (with more intensity) the locations classified as hard or moderate to find than students from the control group.

Therefore, RQ3 can also be answered with a yes, there is an impact, small but positive, of the HUD in the difficulty level of access of locations in the Virtual World, regarding the intensity (frequency) of access. In this sense, again it may be inferred that the heat map have motivated students to turn locations red on the HUD, even the ones harder to find, frequenting it more. This highlights the benefit of a little of gamification implemented in the activity, as the students

sought to complete their HUD while using it. Still, the t-test did not reject the null hypothesis of equality between groups.

To sum up, these new research questions (RQ1, RQ2, RQ3) showed more objective results, which could not be obtained only with students self-reports. This justifies the need and the importance of automatically keeping track of students' interactions in the VW, recording it properly into databases and making it accessible to teachers in an organized way.

However, in spite of some noticeable difference between groups, in all cases all *p*-values were higher than 0.05, not rejecting the null hypothesis at confidence level of 95%. So a caution must be taken to expand the conclusions of this research to a population of students, due to the small sample size analyzed in this study.

VI. CONCLUSIONS AND FUTURE WORK

Virtual Worlds are tools that simulate the real world in 3D, providing teachers with many educational possibilities, as the creation of virtual laboratories [7]. But the lack of autonomous support, while learners are interacting in the environment, might prejudice the experience [19].

In order to contribute with this theme, we have presented a solution that takes advantage of users' context information to present a real-time heat map, using the HUD device available in most VW platforms. The goal is to help on user navigation in the VLE, highlighting places visited according to the frequency of access, keeping students aware of their activities (places visited), and at the same time, personalizing their experience. First results of this application demonstrated that it can increase engagement and interaction time [1].

In this paper we have tried to answer our main research question: ***how is it possible to (1) report and (2) analyze student behavior inside Virtual Worlds?***

To answer (1) we have introduced a web system that allows the teacher to easily extract reports from students' behavior inside the VW, retrieved from sensors implemented using LSL, OSSL and PHP programming languages. This way, the educator does not need to stay monitoring students to evaluate the activity progress, and in consequence, it minimizes possible negative influences of his/her presence on students' immersion and interactivity. Six different types of reports were constructed, allowing to see, for example, locations less visited, which may, in result, indicate the need for adjustments in the environment to improve visitation in those places.

To investigate (2), we have performed a deeper analysis of data from a previous experiment [1], to identify the usefulness of the heat map HUD in providing guidance inside the VW, in order to help the students to reach the learning objectives. Three new research questions were investigated, which using statistical techniques, demonstrated the existence of an impact of the HUD in the extension (number of places visited) and in the intensity (frequency of location visitation) of educational content observation inside the environment. Overall, the results have shown how the contribution of the gamification aspect of the HUD device motivated students to achieve the "red" tag on the heat map, even in places more difficult to find. In this sense, we have also presented some possibilities of data analysis in educational Virtual Worlds.

As the main contribution, we showed that, concerning student guidance, intelligent agents are not the only solution; other types of autonomous support may be helpful. The HUD has as advantages being flexible, as it can be attached to any particular user, and it functions individually, different from common agents that usually are not personalized for each user. In addition, the device is different from common heat maps, which highlight items or places visited by all users. All the tools used are open source, allowing researchers and educators from around the world to reproduce the same or better solutions.

As future works, regarding (1), we plan to integrate the ECO and ICO formulas to the report system, to automatically obtain the levels of student interaction in the VLE, regarding extension (the number of locations/topics visited) and intensity (the frequency of location/topic visit). In the same manner, we intend to include a function to attribute notes for student performance, measured by visit duration or coverage, allowing them to see their own reports after the experience.

Concerning (2), we will apply the VW with the HUD and the reporting system with more teachers, from different areas and environment designs, to compare the results and optimize the tool, gathering data that can be analyzed to increase the validity of results. Based on these new results, we will construct a model to improve student's unsupervised learning process inside Virtual Worlds.

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