A 3D playful framework for learning the components of a wind turbine using Kinect

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ABSTRACT

In this paper, a playful 3D platform using Kinect as a natural means of user interaction to provide a useful teaching resource is described. This platform acquires knowledge of the components and overall operation of a wind turbine. This platform is implemented as an educational game with three levels. Level 1 is responsible for showing the names of the external parts of a wind turbine, level 2 shows the essential behavior of these external parts, and level 3 shows the internal parts and the operation of each of them, as well as the connection that exists between each part of the wind turbine. In addition, each level uses an educational strategy with three fundamental components: content, activity, and evaluation. The content shows the theoretical part of each level, the playful activity consists of a different and increasingly complex puzzle for each level, and the evaluation consists of a series of multiple-choice questions. The results obtained from the tests allow us to conclude that the platform is fully functional and intuitive due to the natural interaction of Kinect and also, the platform presents a safe and risk-free environment where users can learn about wind turbines.

Keywords: Playful 3D framework, Kinect, Educational Strategy, Wind Turbine

INTRODUCTION

The increasing demand for energy in recent years and the need to develop new ways of clean energy production led to the exploration of clean alternatives. One option is the installation of wind farms. Thus, it is necessary to rely on trained staff for the operation of wind turbines which are an essential piece of wind farm technology.

Training rests on knowledge, proper use and maintenance of these machines. However, this knowledge may be difficult to acquire. The difficulty lies in the risks and security measures involved with accessing a specific wind farm or a wind turbine (Pangua Cerrillo, 2014).

Some emergencies could occur in wind farms, particularly during training stages. Workers need to know the parts of a wind turbine and coupling to perform their future activities. During the training, workers are not use to moving within the confined space of a wind turbine. Moreover, they are in constant danger of contact with energized components. Consequently, specific safety and rescue procedures are necessary when considering the following critical activities (Desarrollo Profesional Oshkosh, 2011):
- Working at heights
- Mechanical assembly of large components
- Working with electricity
- Working outdoors
- Installation and assembly of wind turbines

Wind farms are located far from urban areas and thus far from medical or rescue services. The risk of an emergency is considered very serious. The estimated time that rescuers would take to arrive at the site of an accident is too long. For these reasons, the workers responsible for the

assembly and maintenance of wind turbines are extensively trained. In addition, they follow a rigid operational system to minimize risks while working.

Unfortunately, there are few alternatives to learning in a safe environment. The field of computers offers innovative options such as virtual learning environments which allow the users to function as if they were in a real situation but without the hazards. However, current software applications in the field of wind turbines are limited to the general operation, and the simulations are based on fixed perspectives with little interaction. Therefore, a system of virtual reality with natural interaction associated with leisure activities is proposed. Such a system will help the user know, understand and manipulate the components of wind turbines, without being physically in a wind farm and in danger. Given the risks involved when working in or near wind turbines, virtual environments which offer safe learning to the personnel may be advantageous. Any information contained in a virtual environment by itself is not conducive to learning, it is necessary to provide a series of conditions that should favor learning (Herrera, 2004).

For the above mentioned reasons, virtual reality becomes important because its techniques appear to be the best means of data input in the processes of teaching and training (Isea, 2009). In addition, numerous applications establish that knowledge is better retained when there is a direct life experience compared to just seeing or hearing (Ocete, Carrillo and González, 2003). Thus, the idea of having a 3D interactive framework which provides an artificial environment to the user arises. The use of such a framework will encourage learning, knowledge and comprehension of the operation of wind turbine main components. Moreover, the hazards found in a real turbine are not prevailing in the framework, giving the user a safe environment for learning.

Currently, 3D interactive framework has integrated natural user interfaces (NUI) for the interaction process and this has been achieved through devices such as Kinect, which captures the user's body gestures using two cameras and a depth sensor.

Therefore, the objective is to develop an interactive 3D puzzle, using Kinect for the virtual manipulation of the main components of a wind turbine. This interaction is to ensure a good understanding and representation from various perspectives. The following steps were performed to achieve this objective:
1.   Examine and select the hardware and software components to use,
2.   Design and draw the main components of the wind turbine in three dimensions from multiple perspectives, using a 3D videogame engine,
3.   Make the link with the videogame engine to control the perspectives of each component represented in the scenes through Natural User Interfaces (NUI), and
4.   Provide meaningful information about these components.

The educational activities were implemented and interactive exercises were created to measure the user's comprehension with regard to the components of a wind turbine. In addition, system functionality and performance tests were conducted with different computers.

STATE OF THE ART

Within the state of the art, various authors have proposed different ways to include the interactivity provided by Kinect as a learning tool. It has also been proposed as a device for software, with therapeutic purposes as well as for the development of augmented reality applications. The following studies show the versatility of Kinect applications.

One project where a Kinect is used as an interaction device (Mora-lumbreras *et al.*, 2014) focuses on the area of virtual reality. It specifically includes different virtual classrooms, where the learner can move through the application, move the virtual camera which is linked to the position of the head or manipulate the 3D objects through body movements, more specifically hands and feet movements.

Another related study (Morales *et al.*, 2013) presents an application where Kinect replaces the mouse as an interaction device. The application can be implemented to create dynamic classroom exercises in areas where the goal is to learn the names and positions of the parts of an object.

There are numerous applications that emphasize NUI and have been used for various purposes. For example, (León Hernández, 2015) presents an interface that allows hand movement detection and recognition. Visitors at a museum can interact with 3D models of archaeological pieces. Following the same concept of object manipulation, (Lorente & Calafi, 2012) show an application that helps users learn everyday tasks, such as setting the table with dishes, silverware, glasses, etc. This game, created using Kinect interactive applications, had the objective of exploring the features of Microsoft XNA for creating videogames. The learning curve was short.

Another relevant work (Curtidor & Quinche, 2015) adapts a device with a NUI that allows interaction with 3D virtual environments using Kinect which improves the user's immersion experience of a user. A new trend is explored with regard to the use of learning strategies based on gamification and the possibility of using the human body as an interface, which facilitates the interaction between man and machine. For example, in (Benhumea & de la Fraga, 2012) a system translates bodily movements into interaction commands. The properties of the Kinect's depth sensors were used to detect the gestures of users and establish if these gestures allow interaction with the computer.

The following papers, with an emphasis on the use of Kinect show the capabilities with regard to gamification. A notable contribution (Liao & Qu, 2013) proposes a system for training electricians through body movements within an environment developed in Unity 3D.

Another study (Chang et al., 2014) offers a virtual environment for training in the field of mechanical assembly where the learners can use voice commands to navigate with their avatars within a virtual laboratory. They use body movements to combine mechanical parts.

With a focus on learning, (Uribe et al., 2016) proposes the use of virtual laboratories in the field of thermoelectricity. Similarly in (Flanders & Kavanagh, 2015) a virtual reality tool is presented to study the direct kinematics of the arms of a robot. In (Ibánez & Wang, 2015), a multiplayer game that uses bodily gestures, competitive stages and collaborative stages, was developed to help students learn how to recycle, and (Marzo, 2015) proposes an application with sequential missions that represents periodic signals as audible sounds to help students learn concepts, such as frequency, amplitude and sum of signals.

In addition to educational purposes, Kinect has been used for physical and cognitive stimulations in cases of disability. In (González & Rosquete, 2012), with the aim of creating an open system with a highly configurable environment is an example. Likewise, (Sánchez et al., 2014) implements an immersive environment where children can manipulate 3D objects, which helps them improve their senses and body movements. Also, (Navarro et al., 2013) develops an interactive system with the goal of attracting a patient's attention through physical therapy exercises in 3D where the patient is immersed. This system stimulates their interest in interacting with the virtual world.

The use of virtual or multimodal environments provides a meaningful experience to the user, who could be patients. Applications such as (Calleros, J. M. G., 2012) have the goal of returning patients to their daily life activities.

Some papers study the potential of Kinect in the area of augmented reality. In (Ziquan & Zhao, 2012), the users can see themselves displayed on a full screen thanks to a color camera incorporated in the device. The properties of the depth sensors allow the application to take the body parts as activators so the system works as an intelligent changing room.

The authors of (Fernández & Sánchez, 2012) propose an educational augmented reality application, which gives the teacher continuous feedback about students during a class. The teacher will know whether or not students have understood the explanation, if they were able to do an exercise, or if they have any questions during the class.

The use of Kinect in applications involving puzzle solving games with body gestures was also studied. For example, (Konami, 2011) presents a puzzle type videogame where the user tries to solve the puzzles using his own body as a key to the solution. There are different levels and two game modes: single and multiplayer. Similarly, (Aracena, Paredes & Cordova-Gonzales, 2008) presents another educational interactive game, where the objective is to learn while playing through the problem solving process.

Similarly, (KinectHacks, 2011) and (RenderHeads, 2010) present puzzles as an interaction strategy within the application. These puzzles need to be solved with hand gestures, as in (Andreo, 2012) where an application is presented as a small puzzle game that the user needs to solve using an NUI. Certain features from the above mentioned studies were retained to propose a playful framework as an educational strategy for learning the components of a wind turbine:
1.   Create puzzles to encourage learning (Aracena, Paredes & Cordova-Gonzales, 2008; RenderHeads, 2010; KinectHacks, 2011; Konami, 2011),
2.   Use labels to help memorize the names of the parts of an object (Morales et al., 2013),
3.   Consider the commonly used gestures in most applications and change some to facilitate interaction with the user (RenderHeads, 2010; Calleros, J. M. G., 2012; KinectHacks, 2011; Morales et al., 2013; Chang et al., 2014; Mora-lumbreras et al., 2014; León Hernández, 2015).
4.   Develop the playful 3D framework as a videogame since its educational potential has been established (Aracena, Paredes & Cordova-Gonzales, 2008; RenderHeads, 2010; KinectHacks, 2011; Konami, 2011; Sánchez et al., 2014; Ibánez & Wang, 2015; Marzo, 2015) and
5.   Define an educational strategy with levels and missions (Marzo, 2015; Çulha, 2016), a feature which is missing in most of the previously cited papers.

Table 1 shows a comparison between the studies. The last study shown in the table is the current proposal. This research is considered relevant and describes the use of the evaluated variables.

Table 1 shows that seven of the studies present the manipulation of virtual objects. Only the first in the list is not compatible with body movements and does not use Kinect as a means of interaction. Similarly only one study does not present a variety in the scenarios. Six studies are learning tools and six give the user self-visualization.

Table 1. *Comparison with related works*

Study	Manipulation of virtual objects	Compatibility with body movements	Use of Kinect	Variety of scenes	Educational purpose	User visualization
(Fernández Sánchez, 2012)	No	Yes	Yes	Yes	Yes	Not mentioned
(González Rosquete, 2012)	No	Yes	Yes	Yes	No	No
(Lorente & Calafi, 2012)	Yes	Yes	Yes	Yes	No	Yes
(León Hernández, 2015)	Yes	Yes	Yes	Yes	No	Yes
(Mora-lumbreras et al., 2014)	Yes	Yes	Yes	Yes	No	Yes
(Morales et al., 2013)	No	Yes	Yes	Yes	Yes	No
(Navarro *et al.*, 2013)	No	Yes	Yes	Yes	No	Yes
(Benhumea & de la Fraga, 2012)	No	Yes	Yes	Yes	No	No
(Sánchez et al., 2014)	Yes	Yes	Yes	Yes	Yes	No
(Curtidor Quinche, 2015)	No	Yes	Yes	Yes	No	No
(Andreo, 2012)	Yes	Yes	Yes	Yes	Yes	No
(Calleros, J. M. G., 2012)	No	Yes	Yes	Yes	No	No
(Ziquan& Zhao, 2012)	No	Yes	Yes	No	No	Yes
(Hernández Reyna, 2016)	Yes	Yes	Yes	Yes	Yes	Yes

Some tools used in the development of similar studies were incorporated into this research. With regard to libraries, seven studies use the SDK (Software Development Kit) for interaction with the Kinect. With regard to the 3D engine used for creating scenes in the applications, four studies used Unity 3D and the others, which do not require three-dimensional graphics, used other platforms such as XNA Game Studio or Flash. Most of the time, the SDK is used as a bank of gestures to recognize and interpret the movements of the user. ZDK is also used for the same purpose. Our current research uses "Kinect *with* MS-SDK", which has Microsoft SDK libraries implemented.

Unity 3D was used because of the results obtained in performance tests, use and weight of the executable files generated in each one. These tests and results are described in detail in (Hernández Reyna et al., 2015).

METODOLOGY OF DEVELOPMENT OF THE PLAYFUL FRAMEWORK

In the construction of the playful framework, the incremental model of software development described in (Pressman, 2005) is applied as a methodology, taking as essential requirements the characteristics that (Chacon, 2004) proposes for any didactic video game, as well as the strategy of learning described in Enikő (2013).

As part of the development methodology, functional and integration tests were performed for each increment. Once the first version of the playful framework was built, performance tests were carried out to validate the correct functioning of all the increments working as a single System. For such validation, qualitative and quantitative data were collected. The qualitative data were obtained from three users on a scale of 1 to 5 with respect to four basic attributes: videogame flow, functionality, quality of graphics and functionality with Kinect. For the quantitative data, two types of tests were carried out, the first one focused on determining the performance of the hardware in 5 different computer equipment, the second test focused on quantitatively determining the height and ideal distance of the Kinect with respect to the user for the correct recognition of gestures. Each of the stages of the methodology described above is outlined in Figure 1.
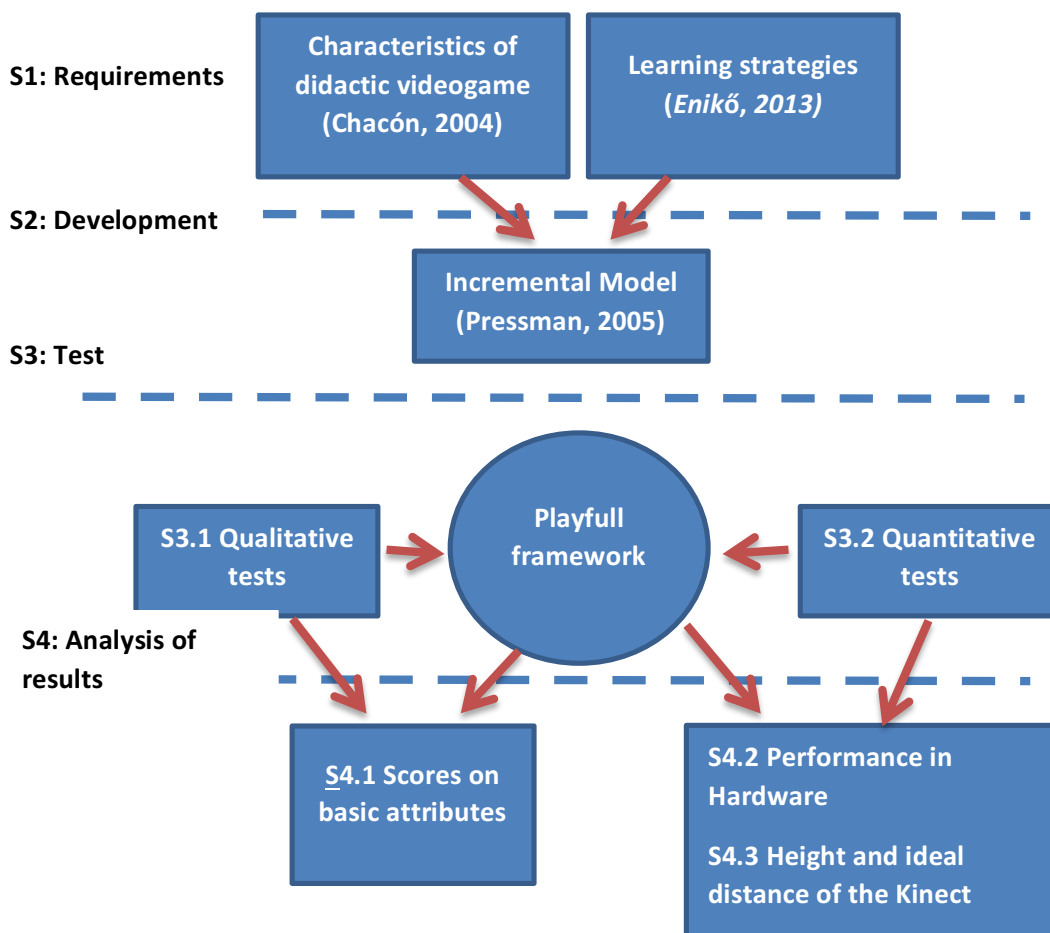
Figure 1. Development methodology

S1.- Considering the main characteristics of the cited research in (Hernández Reyna et al., 2015), it was decided to develop the 3D framework as a videogame following the "Serious Games" trend. The emphasis is on instruction and training in an educational context (Moody *et al.*, 2016).

As well as, the qualities that all educational games must have according to (Chacon, 2004) were considered: a) Didactic intention, b) Learning objectives, c) Rules, limitations and conditions d) Number of players, e) A specific age, f) Fun, g) Tension, h) Teamwork, i) Competition.

In addition, an appropriate didactic strategy for learning based on the theory of knowledge was used, which contains: a) conceptualization, b) repetition and classification, c) application and practice, and d) evaluation (Enikő, 2013).

S2.- An overall development scheme in several stages was proposed. This scheme is in accordance with the incremental model of software engineering which applies linear sequences in a stepwise fashion as the calendar of activities progress. Each linear sequence produces usable software builds. Moreover, such builds are useful for managing technical risks (Pressman, 2005). Each build has four phases: analysis, design, coding and testing. The builds concerning this research are shown in Figure 2 and are described as follows:

- In the first build the users can manipulate objects with their hands using the device.
- In the second build a cursor was added to the scene, so the user has a reference when locating the objects.
- In the third build, the external parts of a wind turbine were depicted in 2D.
- In the fourth build, visual and sound indicators were added to provide feedback to the users on their actions.
- In the fifth build the names of the pieces that need to be placed in the activity are shown, so a new activity that fulfills this requirement was added.
- In the sixth build, a training activity was added to show the names of the gestures and how they are performed to the user. In the seventh build, the levels and missions of the videogame were added.
- Finally, a new level was added in the eighth build. This last level has its own missions and the internal parts of the wind turbine are shown in 3D.

Each build consists of a general operating scheme. The user stands in front of the device and performs hand movements. These movements are captured and sent as a data flow to the Unity 3D asset (Kinect with MS- SDK). The asset identifies the user's gesture and sends the script coded in C #. The script interprets the gesture and sends it to the validation module. This module identifies the action that will be performed according to the gesture and the scene. Then, the action is sent to the Unity 3D and the user is notified via a sound and visual message. Figure 3 describes the process.
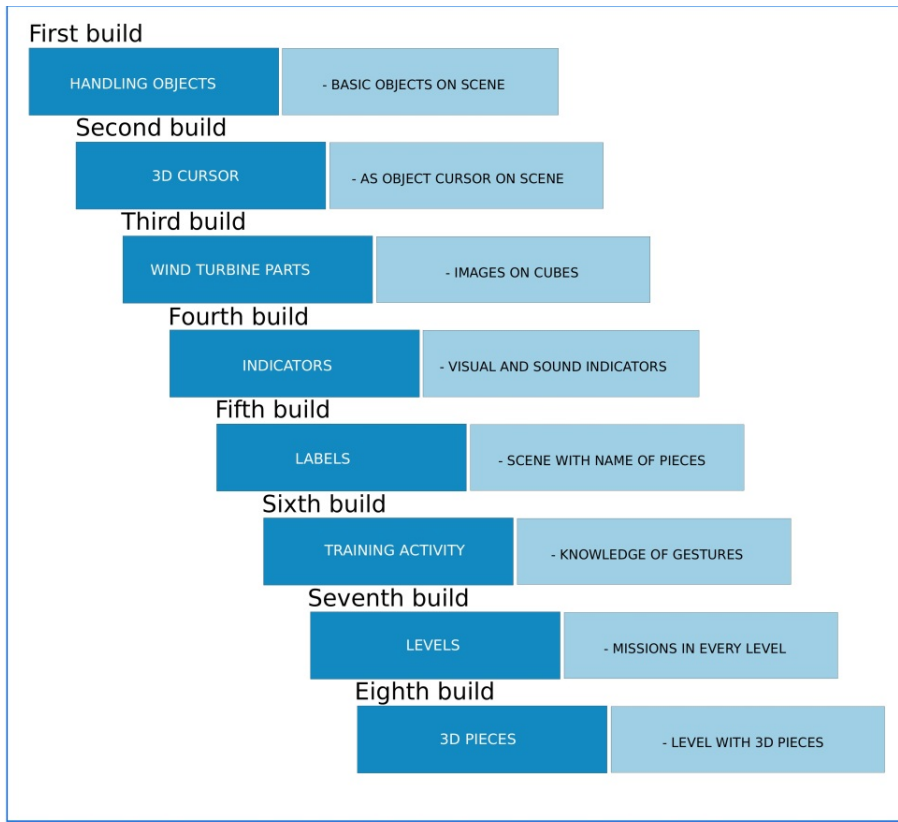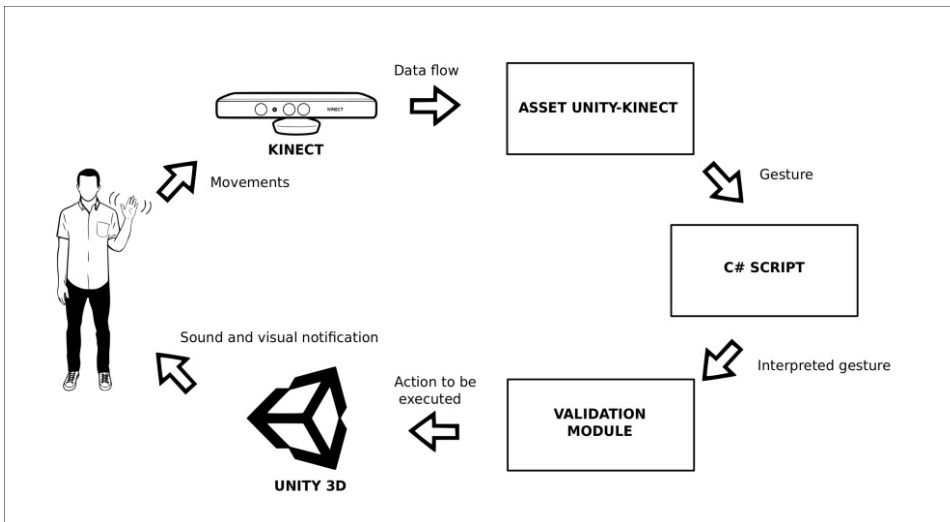
Figure 2. General development scheme

Figure 3. Operational schematic

In the last build, the users record their data as players to log into the game. This will save their progress after registration. To make sure that the user can easily interact with the application, it is necessary to include instructions during the game. The user must first enter into a training stage where the names of the gestures that are used within application and the procedure to perform each gesture are displayed. At the end of the training, the user can access the game. Initially, levels 2 and 3 are blocked. The player must complete level 1 to unlock level 2 and then complete level 2 to unlock 3. Figure 4 illustrates the educational strategy.
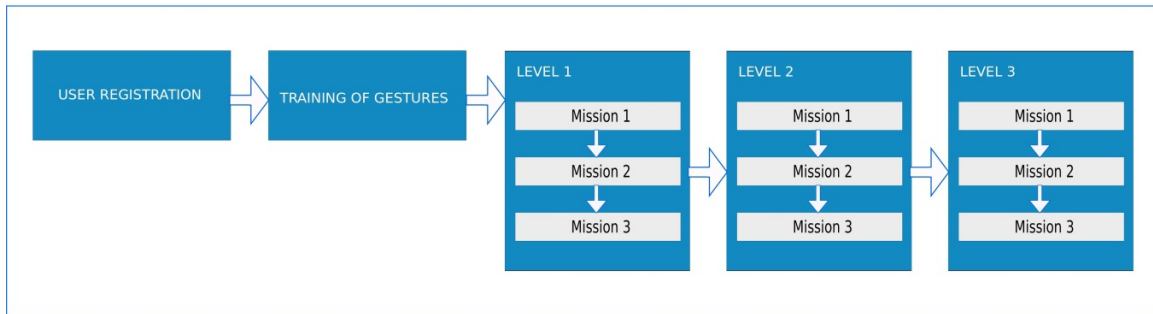
Figure 4. *Educational strategy*

The missions were designed to meet the following objectives: information, activity and evaluation (Enikő, 2013). The use of missions and levels with gradually increasing difficulty contributes to the motivation for learning (Marzo, 2015).

Each level includes three missions which must be accomplished one after the other for the next mission to be enabled. The empirical teaching strategies used by educators (Enikő, 2013) are the benchmark for the missions which consist of: showing the concepts regarding a topic or a phenomenon (information), motivating the student to use this knowledge in a practical way to solve a problem or challenge (activity), and finally assessing the level of knowledge (evaluation). The following three missions are presented in the game:

• **Mission 1: Information -** It provides the information that the user needs to know relative to the level. In the case of level 3, the user interacts with the pieces that will be shown during the game.

• **Mission 2: Activity** - A puzzle type exercise is proposed to the user. At level 1, the user will match the names with the parts, at level 2 the turbine will be properly assembled through placing the outer parts and similarly, and at level 3, the inner parts of the wind turbine will be placed in 3D.

• **Mission 3: Evaluation -** Once the user has understood the theory of mission 1 and has performed the activities of mission 2, there will be an evaluation using a multiple-choice exercise. The questions will be randomly presented.

If the score is within the top three, the player gets bonus medals after completing a mission (except for mission 1). This ensures and promotes competition with other players while fostering interest in improving their performance in the game, which enhances learning. This intrinsic feature of videogames can be associated with the learning methodology based on competitions, which has been successful in other areas of education (Çulha, 2016).

It is important to mention that the medals should be shown to the player on the main screen, and high scores must be visible in this section too. When in first place the player will win the gold medal. A player in second place will get the silver medal, and the bronze is for third place.

S3.1 Qualitative Test: The following tests were conducted with five computers (see Table 2). A player started the game to accomplish the three missions at each level. Features such as functional flow, quality of the graphics, compatibility with Kinect and the overall performance were measured:

• **Functional flow:** It refers to the cursor's response to the gestures, the time it takes for the scenes to load and the system's response to the player's gestures.

• **Quality of the graphics:** This aspect was considered because Unity 3D depicts the objects and scenes with a certain amount of frames per second. Thus, the visual quality varies depending on the performance of the computer that is used.

• **Compatibility with Kinect:** It was analyzed because the asset used for the integration of Kinect in Unity 3D could raise certain functionality problems with some computers.

• **Overall Performance:** it refers to the general behavior of the game. For example if there are failures such as not displaying data, saving wrong information or not performing the appropriate action.

Table 2. Equipment used

Equipment	Model	Processor	Memory	Virtual Memory	Video Card	Operative System
Laptop	**ThinkPad W530**	Intel(R) Core(TM) i7-3610QM CPU @2.30GHz	8 GB	15.2 GB	NVIDIA Quadro K1000M	Windows 7 Professional 64 bits
Laptop	**Latitude E5440**	Intel(R) Core(TM) i7-4600U CPU @2.70GHz	8 GB	15.8 GB	NVIDIA GeForce GT 720M	Windows 7 Professional 64 bits
Laptop	**Inspiron 3521**	Intel(R) Core(TM) i3-3227U CPU @1.90GHz	4 GB	7.88 GB	Intel Graphics	Windows 8.1 Professional 64 bits
PC	**Precision T5810**	Intel(R) Xeon(TM) CPU ES-1620 v3 @3.50GHz	16 GB	31.8 GB	AMD FirePro W5100 (FireGL V) Graphics Adapter	Windows 7 Professional 64 bits
PC	**Precision T7910**	Intel(R) Xeon(TM) CPU ES-2623 v3 @3.00GHz	16 GB	31.8 GB	NVIDIA Quadro K2200	Windows 7 Professional 64 bits

The user was asked to start the videogame and accomplish the missions at each level. While the user was playing, the four aspects of system functionality were assessed. The functionality of a system clearly depends on the specifications of a computer.

S4.1.- The four aspects were scored on a scale of 1 to 5. The best performance was scored 5 while the lowest was scored 1. Table 3 shows the results of the test.

Table 3. Software outcomes

Equipment	Videogame Flow	Funcionality	Quality of Graphics	Funcionality with Kinect	Total
ThinkPad W530	4	5	4	5	18
Latitude E5440	4	5	4	4	17
Inspiron 3521	3	5	3	5	16
Precision T5810	4	5	5	2	16
Precision T7910	4	5	5	4	19

The computer that best performed was scored 5 and was used as a reference to assess the other computers. The results of the evaluation from a spectator point of view were as follows:

ThinkPad W530: Gesture recognition and cursor control are considered acceptable. However, the cursor control is not sufficiently fluid to obtain 5 points. In general, the videogame functions correctly. The laptop's specifications do not allow Unity 3D to represent graphics with the highest quality. However, the asset in the device operated properly without any problems.

Latitude E5440: Gesture recognition and cursor control are acceptable. In general, the video game works properly and the graphics are displayed with good quality. After a certain amount of time, the asset had a problem. The visualization of the player froze and the gesture detection stopped.

Inspiron 3521: This computer has the lowest degree of functionality. The cursor control is slow. Loading the scenes takes time and Unity 3D displays the graphics with low visual quality. Nonetheless, the videogame operated correctly and the asset worked properly and smoothly.

Precision T5810: Gesture recognition and cursor control are acceptable. The overall functionality of the videogame is appropriate. The graphics are displayed with high visual quality. However, this computer had serious problems with the asset. Soon after it started running, the visualization froze and the gesture recognition failed.

Precision T7910: This PC performs best using the videogame. Gesture recognition, cursor control and the scenes work properly. The movement of the scenes and cursor is fluid. The general operation of the videogame is also correct and the graphics have a high visual quality. The only drawback is that after running the game for about 20 minutes, the visualization froze and the gesture recognition failed.

After analyzing the behavior of the videogame in the five computers, hardware tests were conducted to measure the percentage of CPU used and the temperature reached in the GPU while the game runs. The results are presented in the following section.

S3.2 Quantitative Tests (Hardware Performance): Computers are made of different components, such as processors and graphics card, which produce heat while operating. These components are designed to operate under a certain acceptable temperature. If the temperature exceeds this temperature over a long period of time, the components will likely be damaged. Before such a situation, most devices must be turned off to avoid serious problems with their components. The GPU is also tested. The GPU processes multimedia tasks.

S4.2 Results (Hardware Performance): The results of test are shown in Table 4. The scene in the first mission at level 3 allows the user to manipulate 3D animated objects and this requires the highest computer performance. Therefore, this scene was tested for this analysis. The test measured the percentage of CPU use. This measurement was taken while the computer was exclusively running the videogame. The temperature in the GPU was also measured during the test.

Table 4. Hardware outcomes

Equipment	Use of CPU	GPU Temperature
ThinkPad W530	16%	45°
Latitude E5440	49%	58°
Inspiron 3521	88%	59°
Precision T5810	21%	42°
Precision T7910	21%	37°

The ambient temperature during the tests was controlled and kept at 20.9 ° C. The results show that the Inspiron 3521 laptop used 88% CPU and the GPU temperature reached 59 °. The Inspiron 3521 laptop performed poorly compared to the other computers. The ThinkPad W530 used 16%, of the CPU which is below that of the desktops. However, the GPU warmed up somewhat compared with the desktops. These three computers have similar features with regard to the tested scene performance. The PCs had the same percentage of CPU use. However, with regard to temperature, the Precision T5810 reached a temperature of 42 °C in the GPU, while the Precision T7910 warmed up to 37 °C. Both desktops reached temperatures below that of the laptops.

S3.2 Quantitative Tests (Distance and Height Outcomes): According to the manufacturer, the Kinect's range of distance detection is between 0.8 and 4 meters in front. However, the optimal detection area is between 1.2 and 3.5 meters. At this distance, the user is more at ease with regard to gesture detection (Microsoft, 2013). The range of height detection is between 0.8 and 1.6 meters. Tests were conducted to assess gesture behavior with regard to detection at different distances and heights. Three distance values and three height values were considered in all combinations. The tests were conducted using the training scene because this scene includes all the gestures that appear in the videogame. The selected distance points were 1.5, 2.5, and 3 meters with a height of 0.8, 1.2 and 1.4 meters.

The tests consisted of measuring the time the player needed to complete the training scene. At some points the detection affects the correct identification of the gestures and this causes the player to waste time while doing a gesture.

S4.3 Results (*Distance and Height Outcomes*):   Table 5 shows the results of this analysis. Each test was conducted five times. The results shown in table 4 indicate that at a height of 1.2 meters the detection allows gesture recognition without any problems. At a height of 0.8 and 1.4 meters, the detection varies relative to distance. So, at a higher height, a shorter distance is recommended. Conversely, at a lower height, a longer distance is recommended. Additionally, there were some gesture recognition problems, when using the cursor control with the swipe up/down and swipe left/right gestures. Table 6 shows the gesture problems found during the test.

Table 5. Distance and heights outcomes

DISTANCE/ HEIGHT	0.8 m	1.2 m	1.4 m
1.5 m	1.28 min	0.36 min	0.35 min
2.5 m	0.50 min	0.36 min	0.47 min
3 m	0.36 min	0.35 min	0.50 min

Table 6. Gesture Problems

DISTANCE/ HEIGHT	0.8 m	1.2 m	1.4 m
1.5 m	Problems with the cursor	Without any problems	Problems with swipe up/down gestures
2.5 m	Problems with the cursor	Without any problems	Problems with swipe left/right gestures
3 m	Problems with swipe up/down gestures	Without any problems	Problems with swipe left/right gestures

Table 5 shows that distances on a range of 1.5 to 3 meters at a specific height of 1.2 meters correspond to the best times for the handling of the scenes. Table 6 shows that the same distance and height ranges ensure a smooth environment for a good performance of the *Kinect* with the tool. Therefore, it is convenient to place the device at a height of 1.2 meters to handle the tool at distances between 1.5 to 3 meters. A distance of 2.5 meters from the Kinect is most likely the best focal point for gesture recognition and smooth cursor tracking.

At a height of 1.2 meters the gestures work perfectly, detection is instant and the cursor tracking is accurate. However, at a height of 0.8 meters the cursor tracking is not as accurate. At a height of 1.4 meters, swipe left and right gestures are not correctly detected. It should be noted that a 1.62 meters tall player performed these tests and results can vary accordingly.

SCREENSHOTS OF THE PLAYFUL FRAMEWORK

At the beginning of the application a brief introduction is shown which lasts about 22 seconds. Figure 5 shows a part of the scene.
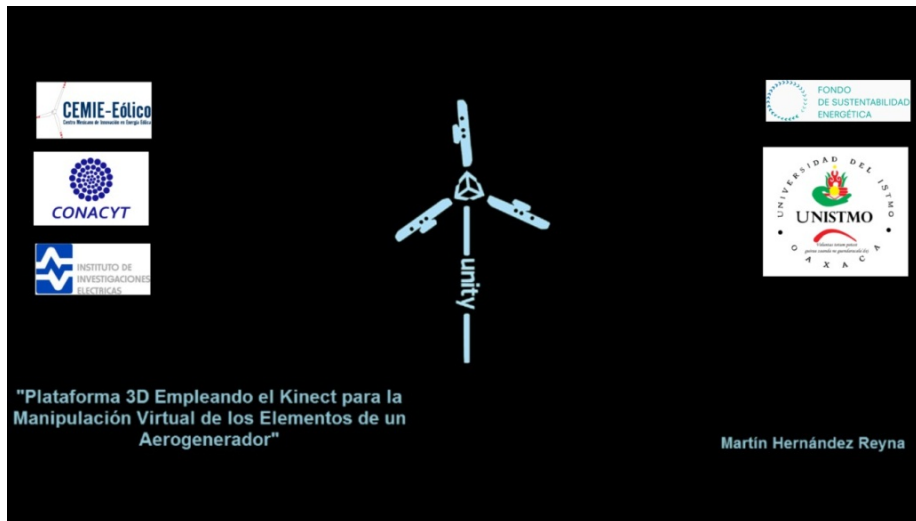

Figure 5. Introduction to the videogame

After the introduction, the main scene is displayed. There are three options: "EXIT", «Registered Player» and "New Player". The "EXIT" option allows the player to close the application. The "Registered Player" option allows the player to enter the game with a user name and password that were previously entered. The remaining option allows any user to create a player profile to access the game as shown in Figure 6 and Figure 7.

Figure 6. Main scenes in the videogame
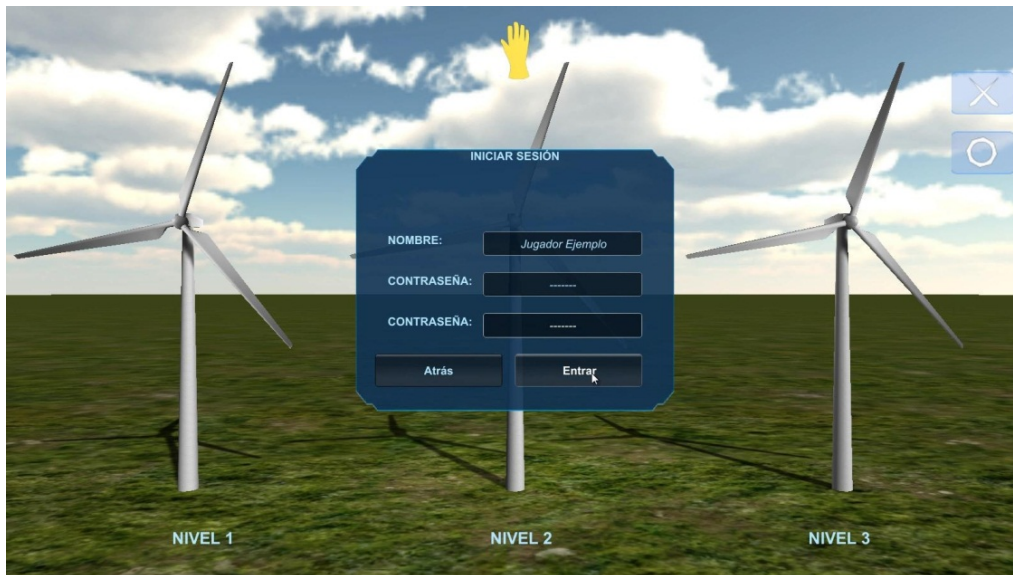
Figure 7. *New player Profile*

Once the user's data are validated, a training scene consisting of two stages is loaded. In the first stage, the gestures and the way they should be performed are shown. In the second stage, the player is asked to perform a short activity to get used to the gestures that will be used during the game. See Figure 8.
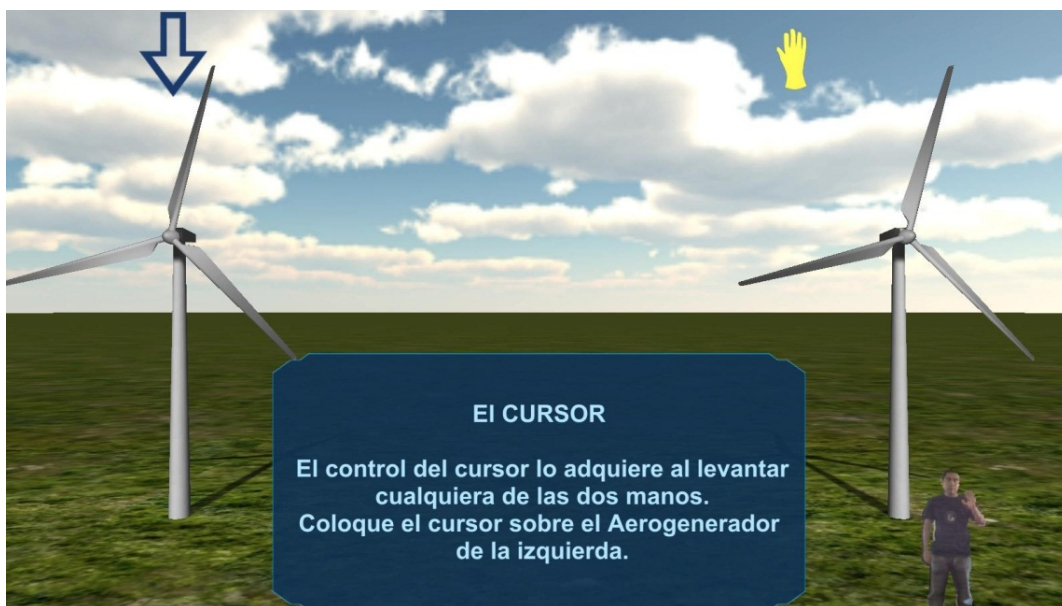
Figure 8. *Training scene (second stage)*

Once the training is completed, the application returns to the main scene so the user can navigate through the three levels of the session as Figure 9 shows.
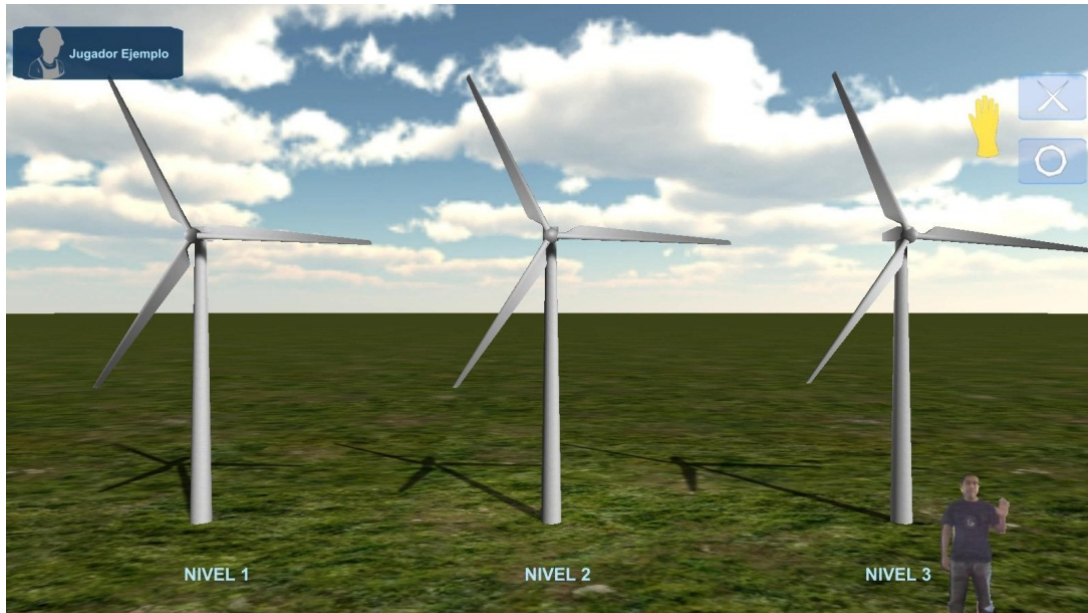
Figure 9. Scene with the player's session started

In addition to the three levels, the player can enter the options that are presented in the upper right corner of the screen. If the player places the cursor on the exit option a confirmation message is displayed to exit the application. Similarly, if the user places the cursor on the option button, a short menu will appear which offers the choices: return to the main menu, log out, see high scores and see the training scene.

The logout option is valuable because if the user leaves the game without closing the session, the application will load the information of the open session the next time the game runs. The high scores option will show the table with the best scores in the missions at each level of the game. Figure 10 and Figure 11 show the exit and option screens, respectively.
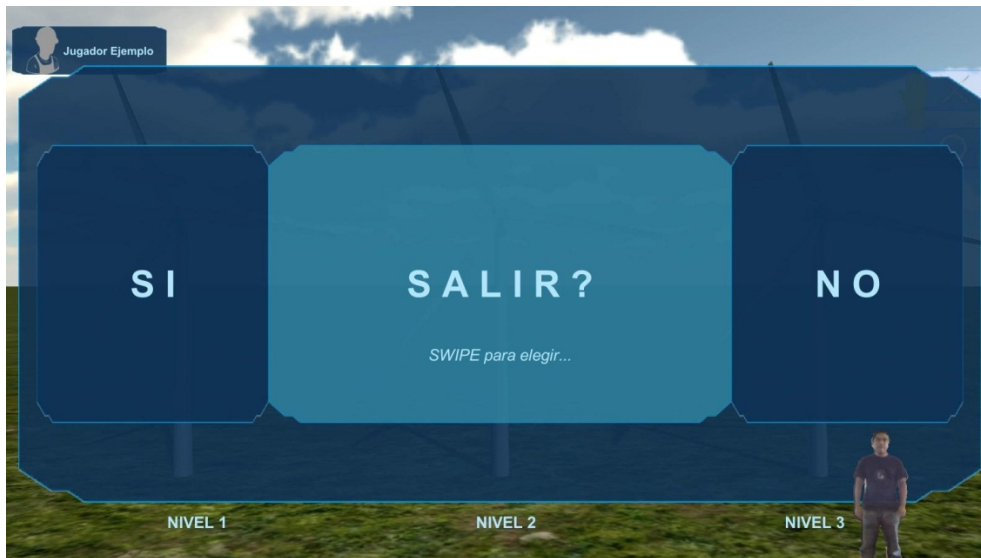
Figure 10. Screen for the exit option
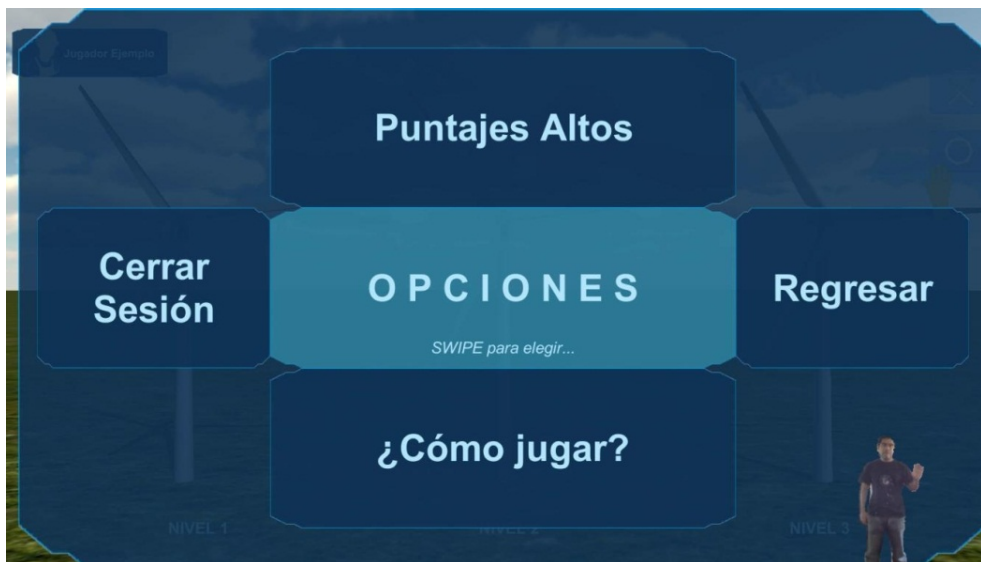
Figure 11. Option screen

As previously described the player can initially access only level 1 and within this level, only the first mission is enabled. The player must complete the mission to enable the following mission. Figure 12 shows the screen of the missions in their respective starting phases with only mission 1 enabled.

Figure 12. *Mission screen for level 1 (starting stage)*

Figures 12-15 show mission 1 of each level. In the case of Level 3 the mission consists of three stages. The first contains an educational text about the part that is displayed, the second allows the user to manipulate certain virtual objects, and the third shows a second educational text.

Figure 13. *Mission 1 of level   1*
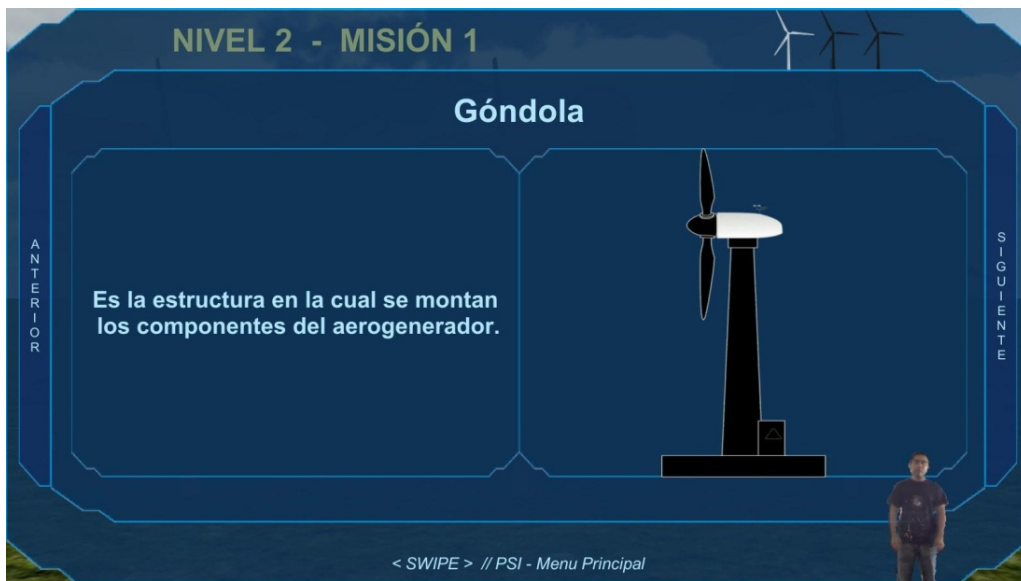
Figure 14. *Mission 1 of level 2*
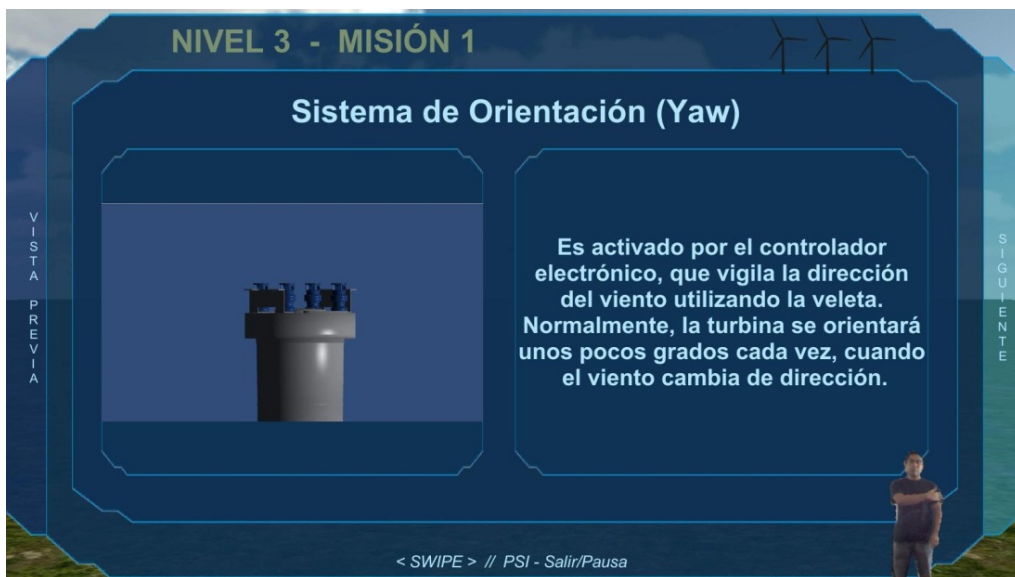
Figure 15. *Mission 1 of level 3 (first stage)*

Figure 16. *Mission 1 of level 3 (second stage)*

Figures 16-18 show mission 2 at each level. Puzzles offer a playful activity. In this mission, the player can win a medal depending on the best time and the least number of mistakes. These factors are compared with those that are presented in the videogame's table of positions.
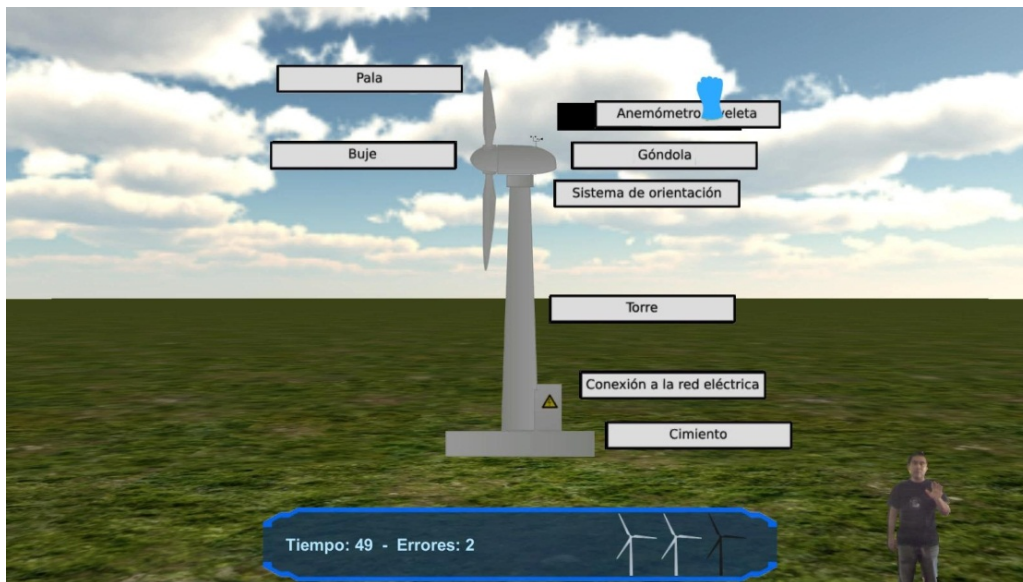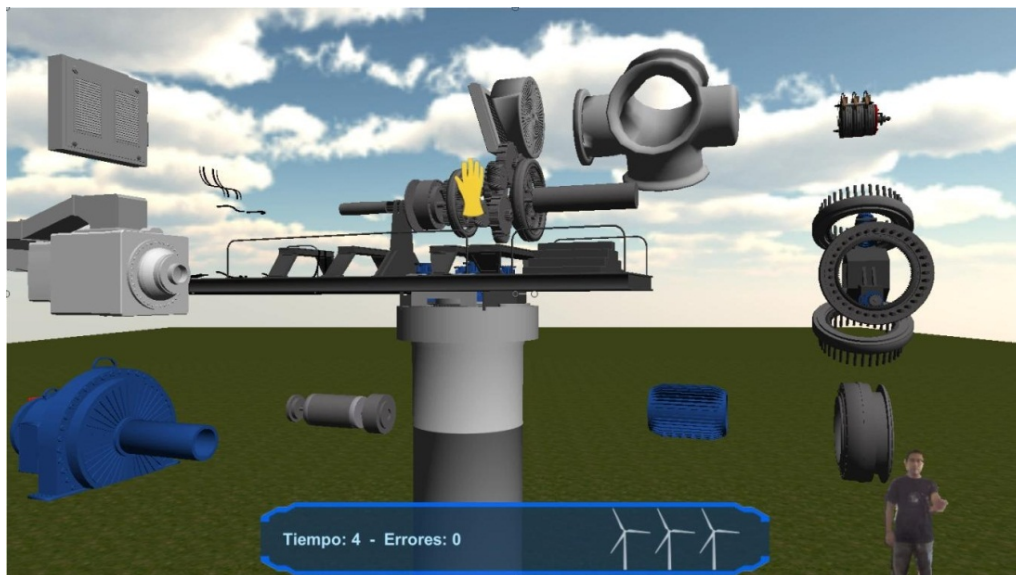

Figure 17. *Mission 2 of level 1*
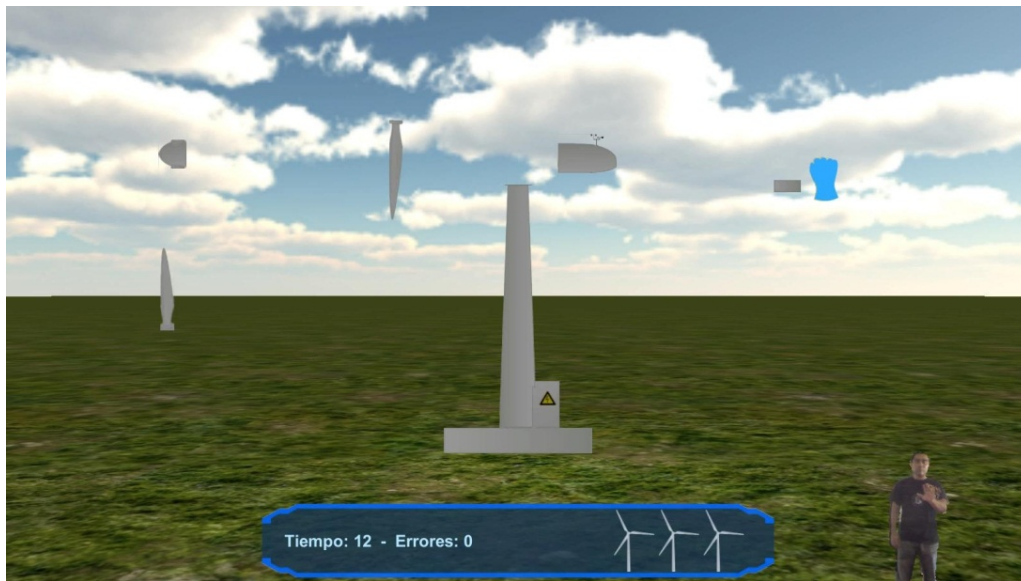
Figure 18. *Mission 2 of level 2*

Figure 19. *Mission 2 of level 3.*

Figures 19-21 show mission 3 at each level. The player needs to select and confirm the response in each question and the game will show if the response is correct. The player can win medals. The results will be shown in the table of positions.
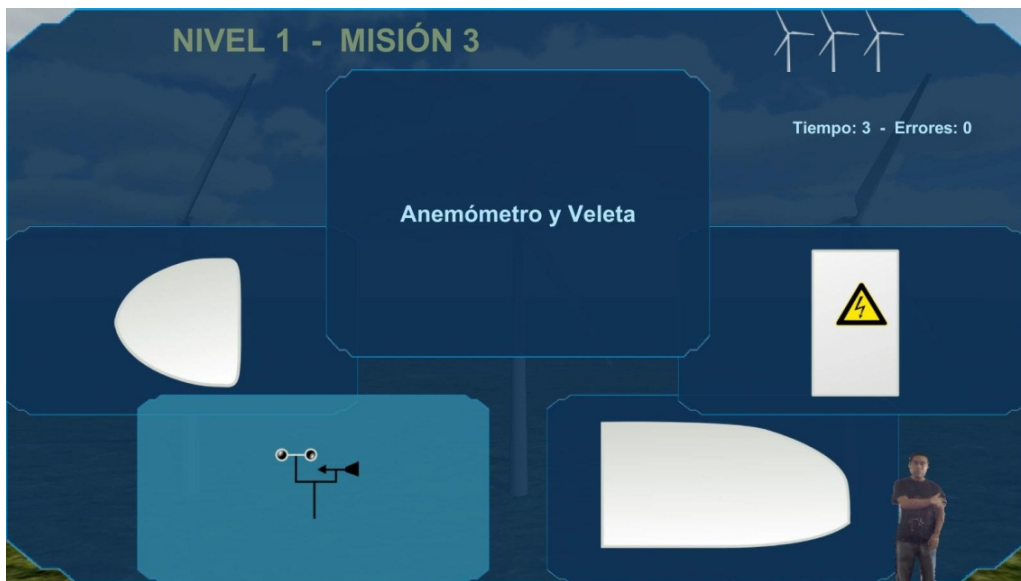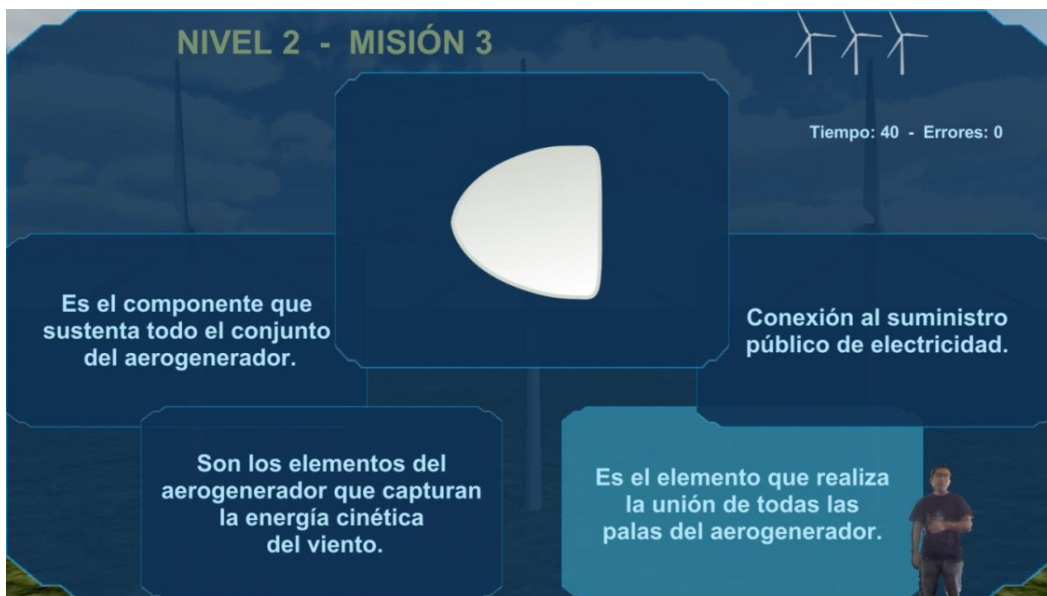
Figure 20. *Mission 3 of level 1*

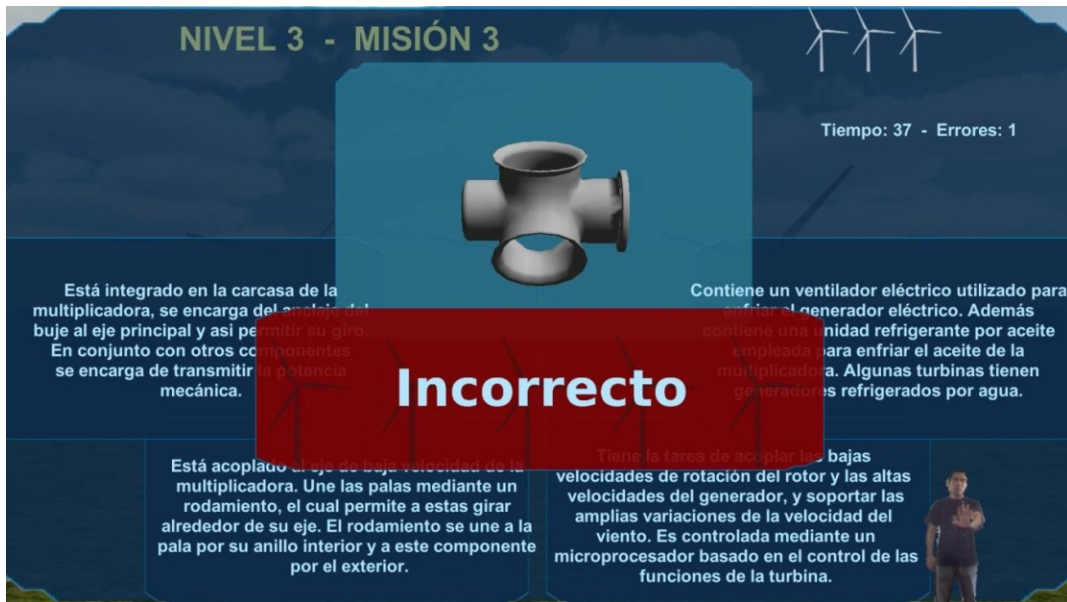**Figure 21.** *Mission 3 of level 2*

Figure 22. *Mission 3 of level 3*

All medals won by a player will be visible next to their name on the main screen. The high scores table will display the data of all players who have won a medal in missions 2 and 3 at each level. Figure 23 and Figure 24 show the main screen of the player and the table of high scores respectively.

Figure 23. *Display of the medals in the main screen*

Figure 24. Table of high scores (Level 2)

CONCLUSION

The concepts of virtual reality applied to a 3D playful framework offer a safe environment where the users interact with a wind turbine without being exposed to the risks associated whit described in (Pangua Cerrillo, 2014; Desarrollo Profesional Oshkosh, 2011). The system covers the main topics of the course "Introduction to wind turbine technology" which is part of the master's degree program at the *Universidad del Istmo*, Tehuantepec campus.

The use of Kinect within the concept of natural interfaces allows the user to easily and intuitively interact with the application. Since the 3D framework is presented as a videogame, the instructions on how to accomplish each mission are given within the game. With practice, the natural interfaces help the inexperienced player become skilled with little effort in a short period of time and effort.

The software tests that were conducted regarding the proposed playful framework showed that it is fully functional. However, to run the application, technologies such as Kinect require the use of a computer with specifications similar to the following: processor Intel(R) Core(TM) i-7 3610QM, 8GB memory, 15.2 GB virtual memory, video card NVIDIA Quadro K1000M and Windows 7 de 64 bits.

With regard to the hardware, the application should be used in an environment with a controlled temperature. The Kinect device has sensors that are in continuous operation during the use of the application and as the application displays 3D objects and environments, it requires high processing capacity. Therefore, a controlled temperature is imperative to prevent overheating of components such as the CPU and the GPU.

To avoid device detection problems by the operating system, when using a Windows 7 operating system, a 2.0 USB port is recommended for the Kinect. However, if the computer runs on a

Windows 8 operating system it is better to use the 3.0 USB port. It is preferable to place the Kinect at a height of 1.2 meters and the user must be at a distance of between 1.5 and 3 meters. A distance of 2.5 meters from the Kinect is probably the best for the gestures to be correctly recognized and the cursor control to be fluid.

With the results of the tests, the platform was found to be fully functional and intuitive due to the Kinect natural interaction. Accordingly, this platform provides a secure environment in which the end user will learn topics related to wind turbines and, their parts and coupling.

FUTURE RESEARCH

The results presented in this article suggest a series of further studies that should provide additional features to the game, as well as, improving education in wind energy:
- Suggest new topics to the subject "Introduction to wind turbine technology"
- Add new enjoyable activities in new missions such as activities that help training users for the maintenance of wind turbines.
- Customize the profile image shown in the game, perhaps with the image of the user or with a personalized avatar.
- Grant bonuses to the user within each mission.
- Create new gestures for the control of the application.
- GRTool (Ibañez and Fanaro, 2013) could be used to create customized gestures.
- With regard to wind turbines, display more internal and external parts or create new activities.
- Implement the option to challenge other players, giving a bonus to the winner.
- Conduct formal and comprehensive studies about usability and student satisfaction as proposed in (Violante and Vezzetti, 2015), to make the necessary changes in further versions.

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