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To my family, I love you all.

"Never give up on a dream just because of the time it will take to accomplish it. The time will pass anyway."

Earl Nightingale

"Hope is not a dream, but a way of making dreams become reality."

Leon Joseph Suenens

"Optimism is the one quality more associated with success and happiness than any other."

Brian Tracy

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Resumo

A interacción humano-computadora (HCI) é un campo crecente de investigación que se centra na relación entre seres humanos e tecnoloxías. HCI busca comprender os métodos que os humanos poden usar para comunicarse coas computadoras e definen novos paradigmas de interacción segundo a tecnoloxía e os dispositivos que se están a desenvolver. Estes novos modelos de interacción teñen unha ampla gama de aplicacións que van desde a investigación ata a industria, o entretemento ou a educación.

Nos últimos anos, a industria dos videojuegos, en busca de experiencias máis interactivas, desenvolveu un conxunto de novos dispositivos e tecnoloxías que proporcionan aos usuarios unha interacción máis natural que un simple gamepad, teclado ou mouse. Estes dispositivos, como Kinect ou Wiimote, permiten o seguimento do corpo e as mans dos xogadores, recoñecendo os seus movementos e xestos, e permiten unha experiencia interactiva máis natural. Estes dispositivos tamén permiten o desenvolvemento de novas aplicacións somatosensoriales que aumentan a inmersión e motivación do usuario, proporcionando xogos máis divertidos.

Recentemente, todas estas ideas, paradigmas -Nova HCI, xogos e dispositivos somatosensoriales combináronse para desenvolver un conxunto de aplicacións xenericamente chamados xogos interactivos de aprendizaxe baseado con xestos (Gigl), que ten como obxectivo mellorar o rendemento na aprendizaxe a través de xogos interactivos . GIGL abre novas oportunidades para aprender contidos complexos utilizando novos paradigmas, por exemplo, a través do movemento do corpo ou as mans, que proporcionan a base de novos modelos de aprendizaxe. Estas técnicas son especialmente interesantes na educación primaria e secundaria por varias razóns. En primeiro lugar, pode crear máis interfaces naturais. En segundo lugar, os estudantes poden usar o seu corpo como ferramenta; isto reduciría a pasividade física e aumentaría a súa motivación. En terceiro lugar, o neno pode ser supervisado polos profesores ao resolver tarefas específicas e os comentarios ao sistema pódense obter en tempo real. Moitos estudos demostran que a GIGL pode aumentar a capacidade de aprendizaxe e as habilidades motrices en diferentes rangos de idade. Non obstante, a educación básica dos nenos debe estimular outros tipos de habilidades no canto de simplemente aprender e adquirir habilidades motoras.

Neste traballo, utilizamos a aprendizaxe interactiva a partir de xogos de xestos (GIGL) para comprobar se estes tipos de aplicacións poden ser adecuados para a estimulación da memoria de traballo (WM) e as habilidades matemáticas básicas (BMS) na infancia temprana (5-6 anos), a través do desenvolvemento dun conxunto de xogos graves baseados en com-

putadores nos que a interacción persona-computadora foi implementada a través dun sistema de recoñecemento de xestos manuais.

O usuario (neno) fai xestos coa man e controla a interacción co xogo. A captura de movemento foi desenvolvida usando o dispositivo Kinect, mentres que o motor gráfico Unity 3D foi elixido para o desenvolvemento das interfaces do xogo. As funcións executivas (EF) son habilidades cognitivas baseadas no cerebro que facilitan, esencialmente, o pensamento ea autorregulación. As funcións executivas baséanse no córtex prefrontal do noso cerebro e axudan a establecer metas e tomar decisións. Existen tres tipos principais de funcións executivas: memoria de traballo, control inhibitorio e flexibilidade cognitiva, e estas son as que imos traballar no desenvolvemento dun sistema de oito xogos baseado en GIGL.

Como o sistema foi desenvolvido para ser usado por nenos pequenos de 5-6 anos de idade, o tipo de interacción debe ser moi sinxelo. Utilizamos só un pequeno conxunto de xestos: seleccionar, arrastrar, soltar. Estes xestos son, en xeral, normais en todas as aplicacións e os dispositivos deben recoñecelos sen problemas. O obxectivo da actividade era involucrar aos participantes en arrastrar e soltar accións co Kinect. As accións de arrastrar e soltar foron implementadas do seguinte xeito: o usuario podería seleccionar o obxecto desexado movendo o punteiro de Kinect, que é unha man na pantalla, sobre el e logo pechando a palma. Entón podían arrastralo ao lugar correcto movendo a man mentres mantén a palma pechada e deixando caer abrindo a palma da man. O usuario pode usar calquera man.

Este sistema ten unha aplicación backoffice que permite a configuración. Está baseado nunha base de datos MySQL xestionada con PHP MyAdmin, que é unha ferramenta de código aberto gratuíta escrita en PHP que permite a xestión de MySQL a través dun navegador web. os alumnos eo profesor, pode definir propiedades específicas sobre o sistema que se relacionan co desenvolvemento dos xogos, máis: unha páxina web usando PHP e HTML para aplicacións de xestión de configuración identificaron dúas principais actores foi creado rexistra os teus alumnos. A través do sitio web, o profesor pode crear un perfil para cada neno que conteña o seu nome, peso, altura e unha foto, para ser usado na GIGL. O sistema permite xerar informes sobre a interacción de diferentes alumnos para que o profesor poida analizar a súa evolución.

A investigación conducida en colaboración co grupo GIPDAE Universidade Coruña, foi desenvolvido a partir dun deseño case experimental con pre-ensaio e de post-ensaio, empregando tanto un grupo experimental e un control a través de tres fases : o primeiro foi a avaliación previa das habilidades do alumno; unha segunda fase na que se desenvolveu o uso da tecnoloxía; e unha fase final de avaliación. Na fase de avaliación, a memoria de traballo

foi medido utilizando o Corsi tarefas e habilidades matemáticas básicas mediante o exame para o diagnóstico de habilidades matemáticas básicas (TEDI-Math). Esta parte da avaliación dos diferentes xogos propostos, así como gran parte do seu deseño, foi realizada polo grupo GIPDAE.

A principal contribución deste estudo é demostrar que, nunha fase moi temperá da infancia, pódese observar que as funcións executivas, con foco na memoria de traballo pode ser mellorada e impactar positivamente habilidades matemáticas desenvolvidas a través Gigl. Esta hipótese foi probada experimentalmente por unha proba estándar, que mostra un aumento nas habilidades cognitivas dos nenos a través do xogo de ordenador. O conxunto de aplicacións desenvolvidas co paradigma GIGL supera as limitacións das interfaces tradicionais empregadas na educación infantil, como o teclado, o mouse ou o gamepad.

A integración dun dispositivo como Kinect nun motor gráfico como Unity3D e bases de datos do xestor de luz como MySQL permitiunos desenvolver un conxunto de 8 xogos educativos interactivos, que foron validadas por expertos en educación e nos permitiron traballar con nenos A idade preescolar en termos de funcións executivas refírese a: memoria de traballo, control inhibitorio e flexibilidade cognitiva.

Palabras chave: Habilidades Matemáticas Básicas, Educación Infantil, Xestos, Aprendizaxe Interactiva Xogo, Interacción Humano-Informática, Memoria de Traballo.

Resumen

La interacción persona-ordenador (HCI) es un campo de investigación en crecimiento que se centra en la relación entre los seres humanos y las tecnologías. HCI busca entender los métodos que los humanos pueden usar para comunicarse con las computadoras y define nuevos paradigmas de interacción de acuerdo con la tecnología y los dispositivos que se están desarrollando. Estos nuevos modelos de interacción tienen una amplia gama de aplicaciones que van desde la investigación hasta la industria, el entretenimiento o la educación.

En los últimos años, la industria de los videojuegos, en busca de experiencias más interactivas, ha desarrollado un conjunto de nuevos dispositivos y tecnologías que proporcionan a los usuarios una interacción más natural que la que puede ofrecer un simple gamepad, teclado o ratón. Estos dispositivos, como Kinect o Wiimote, permiten el seguimiento del cuerpo y las manos de los jugadores, reconociendo sus movimientos y gestos, y permiten una experiencia interactiva más natural. Estos dispositivos también permiten el desarrollo de nuevas aplicaciones somatosensoriales que aumentan la inmersión y motivación del usuario, proporcionando juegos más entretenidos.

Recientemente, todas estas ideas -nuevos paradigmas HCI, juegos y dispositivos somatosensoriales se han combinado para desarrollar un conjunto de aplicaciones llamadas genéricamente aprendizaje basado en juegos interactivos con gestos (GIGL), cuyo objetivo es mejorar el rendimiento del aprendizaje a través de juegos interactivos. GIGL abre nuevas oportunidades para aprender contenidos complejos utilizando nuevos paradigmas, por ejemplo, a través del movimiento del cuerpo o de las manos, que proporcionan una base para nuevos modelos de aprendizaje. Estas técnicas son especialmente interesantes en la educación primaria y secundaria por varias razones. En primer lugar, se pueden crear interfaces más naturales. En segundo lugar, los alumnos pueden utilizar su cuerpo como herramienta; esto reduciría la pasividad física y aumentaría su motivación. En tercer lugar, el niño puede ser supervisado por los profesores mientras resuelve tareas específicas, y la retroalimentación al sistema puede obtenerse en tiempo real. Muchos estudios muestran que el GIGL puede aumentar tanto la capacidad de aprendizaje como las habilidades motoras en diferentes rangos de edades. Sin embargo, la educación básica de los niños debería estimular otros tipos de capacidades en lugar de simplemente aprender y adquirir competencias motoras.

En este trabajo, utilizamos el aprendizaje interactivo basado en juegos de gestos (GIGL) para comprobar si este tipo de aplicaciones pueden ser adecuadas para la estimulación de la memoria de trabajo (WM) y las habilidades matemáticas básicas (BMS) en la primera infancia

(5-6 años), mediante el desarrollo de un conjunto de juegos serios, basados en el ordenador, en los que la interacción persona-ordenador se ha implementado mediante un sistema de reconocimiento de gestos con las manos.

El usuario (niño) hace gestos con la mano y controla la interacción con el juego. La captura de movimiento se ha desarrollado utilizando el dispositivo Kinect, mientras que para el desarrollo de las interfaces del juego se ha elegido el motor gráfico Unity 3D.

Las funciones ejecutivas (EF) son habilidades cognitivas basadas en el cerebro que facilitan, esencialmente, el pensamiento y la autorregulación. Las funciones ejecutivas se basan en la corteza prefrontal de nuestro cerebro y ayudan a establecer metas y a tomar decisiones. Existen tres tipos principales de funciones ejecutivas: memoria de trabajo, control inhibitorio y flexibilidad cognitiva, y son estas las que vamos a trabajar con el desarrollo de un sistema de ocho juegos basado en GIGL.

Como el sistema ha sido desarrollado para ser utilizado por niños muy pequeños de 5-6 años, el tipo de interacción tiene que ser muy simple. Usamos sólo un pequeño conjunto de gestos: seleccionar, arrastrar, soltar. Estos gestos son, en general, estándar en todas las aplicaciones y los dispositivos deben reconocerlos sin problemas. El propósito de la actividad era involucrar a los participantes en acciones de arrastrar y soltar con el Kinect. Las acciones de arrastrar y soltar se implementaron de la siguiente manera: el usuario podía seleccionar el objeto deseado moviendo el puntero Kinect, que es una mano en la pantalla, sobre él, y cerrando su palma después. Entonces podrían arrastrarlo al lugar correcto moviendo la mano mientras mantienen la palma cerrada y dejarlo caer abriendo la palma de la mano. El usuario puede usar cualquier mano.

Es sistema cuenta con una aplicación de backoffice que permite la configuración. Está basada en una base de datos MySQL gestionada con PHP MyAdmin, que es una herramienta gratuita de código abierto escrita en PHP que permite administrar MySQL a través de un navegador web. Se creó una página web usando PHP y HTML para la gestión de la configuración de las aplicaciones Hemos identificado dos actores principales: los propios alumnos y el profesor, que puede configurar propiedades específicas en el sistema que se refieren al desarrollo de los juegos, además de registrar a sus alumnos. A través de la página web, el profesor puede crear un perfil para cada niño que contenga su nombre, peso, estatura y una foto, para ser utilizado en el GIGL. El sistema permite generar informes sobre la interacción de los diferentes alumnos para que el profesor pueda analizar su evolución.

La investigación, realizada en colaboración con el grupo GIPDAE de la Universidad de A Coruña, se desarrolló a partir de un diseño cuasi-experimental con pre-test y post-test, utilizando tanto un grupo experimental como uno de control a través de tres fases: la primera fue la evaluación previa de las habilidades del alumno; una segunda fase en la que se desarrolló el uso de la tecnología; y una fase final de evaluación. En las fases de evaluación, la memoria de trabajo se midió utilizando el Corsi Task, y las habilidades matemáticas básicas utilizando la prueba para el diagnóstico de competencias matemáticas básicas (TEDI-MATH). Esta parte de la evaluación de los diferentes juegos propuestos, así como gran parte de su diseño, ha sido realizada por el grupo GIPDAE.

La principal contribución de este estudio es demostrar que en una etapa muy temprana de la infancia, se puede observar que las funciones ejecutivas, con un enfoque en la memoria de trabajo, pueden ser mejoradas e impactar positivamente las habilidades matemáticas desarrolladas a través de GIGL. Esta hipótesis fue probada experimentalmente por una prueba estándar, que muestra un aumento en las capacidades cognitivas de los niños a través del juego de ordenador. El conjunto de aplicaciones desarrolladas con el paradigma GIGL supera las limitaciones de las interfaces tradicionales utilizadas en la educación de la primera infancia, como el teclado, el ratón o el gamepad.

La integración de un dispositivo como Kinect en un motor gráfico como UNITY3D y un gestor de bases de datos ligero como MySQL nos ha permitido desarrollar un conjunto de 8 juegos educativos interactivos, que han sido validados por expertos en educación y nos han permitido trabajar con niños en edad preescolar en cuanto a funciones ejecutivas se refiere: memoria de trabajo, control inhibitorio y flexibilidad cognitiva.

Palabras clave: Habilidades Matemáticas Básicas, Educación Infantil Temprana, Aprendizaje Interactivo Basado en Juegos de Gestos, Interacción Humano-Computadora, Memoria de Trabajo

Summary

Human-computer interaction (HCI) is a growing field of research which focuses on the relation between humans and technologies. HCI seeks to understand the methods that humans can use to communicate with computers and defines new interaction paradigms according as technology and the devices are progressing. These new interaction models have a wide range of applications ranging from research to industry, entertainment, or education. enhancing playing and learning for children is one of the most common uses of human-computer interaction.

In recent years, the games industry, looking for more interactive experiences, has developed a set of new devices and technologies that provide users with a more natural interaction than a simple gamepad, keyboard, or mouse can offer. These devices, such as Kinect, or Wiimote, allow tracking of the body and hands of the players, recognizing their movements and gestures, and allow a more natural interactive experience. These devices also allow the development of new somatosensory applications which increase user immersion and motivation, providing more entertaining games.

Recently, all these ideas - new HCI paradigms, games, and somatosensory devices have been combined to develop a set of applications generically called gesture interactive game-based learning (GIGL), which aims to improve learning performance through interactive games. GIGL opens up new opportunities to learn complex content using new paradigms, for example, through movement of the body or hands, which provide a basis for new learning models. These techniques are especially interesting in primary and secondary education for several reasons. Firstly, more natural interfaces can be created. Secondly, learners can use their body as a tool; this will reduce physical passivity and increase their motivation. Thirdly, the child can be supervised by teachers while solving specific tasks, and feedback to the system can be obtained in real time. Many studies report that GIGL can increase both the ability to learn and motor skills in different ranges of ages. However, the overall education of children should stimulate other kinds of abilities rather than simply learning and motor competences.

In this work, Gesture interactive game-based learning (GIGL) was used to test whether these types of applications were suitable for the stimulation of working memory (WM) and basic mathematical skills (BMS) in early childhood (5-6 years) by developing a set of serious games, based on computer, in which the interaction person-computer has been implemented

using a system of recognition of gestures with hands. The user (child) gestures with the hand and controls the interaction with the game. Motion capture has been developed using the Kinect device, while for the development of the game interfaces, the Unity 3D graphics engine has been chosen.

Executive functions (EF) are brain-based cognitive feature skills that facilitate, essentially, thought and self-regulation. Executive functions are based in the prefrontal cortex of our brains and assist with goal-setting and decision-making. There are three main types of executive functions: working memory, inhibitory control, and cognitive flexibility.

As the system has been developed to be used for very young children 5-6 years old, the type of interaction has to be very simple. We used only a short set of gestures; select, drag, drop. These gestures are, in general, standard to every application and the devices should recognize them without problems. The purpose of the activity was to engage the participants in drag and drop actions with the Kinect. The drag and drop actions were implemented as follows: the user could select the desired object by moving the Kinect pointer, which is a hand on screen, over it, and closing their palm after. Then they could move it to the correct place by moving their hand while keeping the palm closed and drop it by opening their palm. The user could use either hand.

The MySQL database was linked to PHP MyAdmin, which is a free, open-source tool written in PHP that can administer MySQL through a web browser. A website system was created using PHP and HTML. We have identified two main actors: the students themselves, and the teacher who can configure specific properties in the system that concern the development of the games, in addition to registering their students. Through this system, the teacher can create a profile for each child containing his name, weight, height, and a photo, to be used in the GIGL. The system allows generating reports on the interaction of the different students so that the teacher can analyze their evolution.

The research, carried out in collaboration with the GIPDAE group of the University of A Coruña, was developed from a quasi-experimental design with pre-test and post-test, using both an experimental and a control group through three phases: the first was the previous evaluation of the student's skills; a second phase in which the use of technology was developed; and a final phase of evaluation. In the evaluation phases, the working memory was measured by using the Corsi Task, and the basic mathematical skills by using the test for the diagnosis of basic mathematical competences (TEDI-MATH). This part of the evaluation of the different proposed games, as well as a large part of their design, has been carried out by the GIPDAE group.

The main contribution of this study is proving that at a very early stage of childhood, it can be observed that the executive functions, with a focus on working memory, can be improved and positively impact the mathematical skills developed through GIGL. This hypothesis was proven experimentally by a standard test, which shows an increase in children's cognitive abilities through computer game play. The set of applications developed with the GIGL paradigm overcome the limitations of traditional interfaces used in early childhood education, such as the keyboard, mouse or gamepad.

The integration of a device such as Kinect in a graphics engine such as UNITY3D and a lightweight database manager such as MySQL has allowed us to develop a set of interactive educational games, which have been validated by educational experts and have allowed us to work with pre-school children regarding executive functions.

Keywords: Basic Mathematical Skills, Early Childhood Education, Gesture Interactive Game-Based Learning, Human-Computer Interaction, Working Memory

Resumen extendido

La interacción persona-ordenador (HCI) es un campo de investigación en crecimiento que se centra en la relación entre los seres humanos y las tecnologías. HCI busca entender los métodos que los humanos pueden usar para comunicarse con las computadoras y define nuevos paradigmas de interacción de acuerdo con la tecnología y los dispositivos que se están desarrollando. Estos nuevos modelos de interacción tienen una amplia gama de aplicaciones que van desde la investigación hasta la industria, el entretenimiento o la educación.

En los últimos años, la industria de los videojuegos, en busca de experiencias más interactivas, ha desarrollado un conjunto de nuevos dispositivos y tecnologías que proporcionan a los usuarios una interacción más natural que la que puede ofrecer un simple gamepad, teclado o ratón. Estos dispositivos, como Kinect o Wiimote, permiten el seguimiento del cuerpo y las manos de los jugadores, reconociendo sus movimientos y gestos, y permiten una experiencia interactiva más natural. Estos dispositivos también permiten el desarrollo de nuevas aplicaciones somatosensoriales que aumentan la inmersión y motivación del usuario, proporcionando juegos más entretenidos.

Recientemente, todas estas ideas -nuevos paradigmas HCI, juegos y dispositivos somatosensoriales se han combinado para desarrollar un conjunto de aplicaciones llamadas genéricamente aprendizaje basado en juegos interactivos con gestos (GIGL), cuyo objetivo es mejorar el rendimiento del aprendizaje a través de juegos interactivos. GIGL abre nuevas oportunidades para aprender contenidos complejos utilizando nuevos paradigmas, por ejemplo, a través del movimiento del cuerpo o de las manos, que proporcionan una base para nuevos modelos de aprendizaje. Estas técnicas son especialmente interesantes en la educación primaria y secundaria por varias razones. En primer lugar, se pueden crear interfaces más naturales. En segundo lugar, los alumnos pueden utilizar su cuerpo como herramienta; esto reduciría la pasividad física y aumentaría su motivación. En tercer lugar, el niño puede ser supervisado por los profesores mientras resuelve tareas específicas, y la retroalimentación al sistema puede obtenerse en tiempo real. Muchos estudios muestran que el GIGL puede aumentar tanto la capacidad de aprendizaje como las habilidades motoras en diferentes rangos de edades. Sin embargo, la educación básica de los niños debería estimular otros tipos de capacidades en lugar de simplemente aprender y adquirir competencias motoras.

Garris propuso el modelo de Entrada-Proceso-Resultado (IPO), que ha sido adoptado como un paradigma tácito para la mayoría de los estudios sobre juegos de aprendizaje. El modelo IPO delimita tres elementos: (1) La Entrada, que ilustra el diseño del proceso instruccional; (2) el proceso, que introduce el ciclo del juego y permite la retroalimentación del usuario sobre sus experiencias; y (3) el resultado, a través del cual se realiza un análisis exhaustivo de los objetivos y resultados de la capacitación . hemos adoptado el modelo IPO para el diseño e implementación de una aplicación de aprendizaje basada en el gesto con el fin de mostrar que los procesos que subrayan las habilidades conscientes, como la memoria de trabajo, pueden ser reforzados.

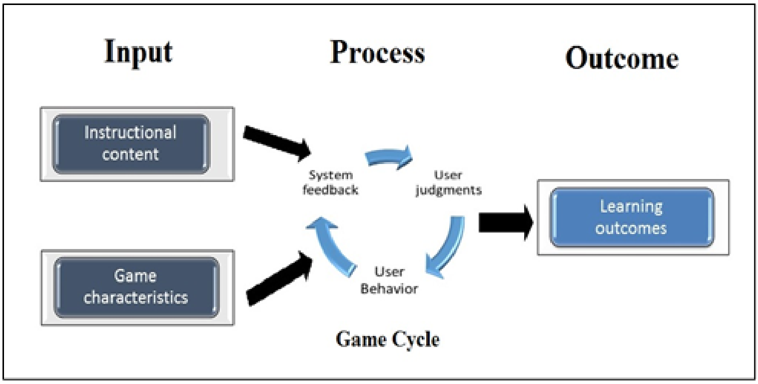


Figure 1: IPO game-based learning model.

En este trabajo, utilizamos el aprendizaje interactivo basado en juegos de gestos (GIGL) para comprobar si este tipo de aplicaciones pueden ser adecuadas para la estimulación de la memoria de trabajo (WM) y las habilidades matemáticas básicas (BMS) en la primera infancia (5-6 años), mediante el desarrollo de un conjunto de juegos serios, basados en el ordenador, en los que la interacción persona-ordenador se ha implementado mediante un sistema de reconocimiento de gestos con las manos. El proceso que seguimos para incorporar el gesto es el siguiente:

1. Los niños juegan delante del sistema, repitiendo varias veces el mismo gesto, de forma que se graba una serie de ejemplos de muestra. Para ello se utiliza Microsoft Kinect Studio V2. Se necesitan al menos dos secuencias para cada gesto: una para entrenar el sistema y otra como prueba para comprobar la eficacia de los resultados del reconocimiento. Este paso se desarrolla en una aplicación de prueba.

2. La caracterización de la grabación es realizada por un experto humano, indicando al sistema en qué momentos se está realizando el gesto (cuándo comienza y cuándo termina) a través de una línea de tiempo mediante el uso de Visual Gesture Building que permite entrenar al sistema y codificar el gesto en un archivo.

3. El sistema se entrena utilizando el algoritmo Adaboost que permite que un sensor caracterice cualquier gesto generado. La eficacia de la detección de cada gesto específico se comprueba utilizando los datos obtenidos como archivo de grabación de prueba.

El usuario (niño) hace gestos con la mano y controla la interacción con el juego. La captura de movimiento se ha desarrollado utilizando el dispositivo Kinect, mientras que para el desarrollo de las interfaces del juego se ha elegido el motor gráfico Unity 3D.

Las funciones ejecutivas (EF) son habilidades cognitivas basadas en el cerebro que facilitan, esencialmente, el pensamiento y la autorregulación. Las funciones ejecutivas se basan en la corteza prefrontal de nuestro cerebro y ayudan a establecer metas y a tomar decisiones. Existen tres tipos principales de funciones ejecutivas: memoria de trabajo, control inhibitorio y flexibilidad cognitiva, y son estas las que vamos a trabajar con el desarrollo de un sistema de ocho juegos basado en GIGL.

Como el sistema ha sido desarrollado para ser utilizado por niños muy pequeños de 5-6 años, el tipo de interacción tiene que ser muy simple. Usamos sólo un pequeño conjunto de gestos: seleccionar, arrastrar, soltar. Estos gestos son, en general, estándar en todas las aplicaciones y los dispositivos deben reconocerlos sin problemas. El propósito de la actividad era involucrar a los participantes en acciones de arrastrar y soltar con el Kinect. Las acciones de arrastrar y soltar se implementaron de la siguiente manera: el usuario podía seleccionar el objeto deseado moviendo el puntero Kinect, que es una mano en la pantalla, sobre él, y cerrando su palma después. Entonces podrían arrastrarlo al lugar correcto moviendo la mano mientras mantienen la palma cerrada y dejarlo caer abriendo la palma de la mano. El usuario puede usar cualquier mano.

Es sistema cuenta con una aplicación de backoffice que permite la configuración. Está basada en una base de datos MySQL gestionada con PHP MyAdmin, que es una herramienta gratuita de código abierto escrita en PHP que permite administrar MySQL a través de un navegador web. Se creó una página web usando PHP y HTML para la gestión de la configuración de las aplicaciones Hemos identificado dos actores principales: los propios alumnos y el profesor, que puede configurar propiedades específicas en el sistema que se refieren al desarrollo de los juegos, además de registrar a sus alumnos. A través de la página web, el profesor puede crear un perfil para cada niño que contenga su nombre, peso, estatura y una foto, para ser utilizado en el GIGL. El sistema permite generar informes sobre la interacción de los diferentes alumnos para que el profesor pueda analizar su evolución.

El sistema ha sido validado en un colegio público de Galicia. Se escogió un grupo experimental, que podía trabajar de forma individual, en parejas o en grupos de cinco. Este grupo realizó tres sesiones semanales de treinta minutos en un área específica del aula. La duración del programa fue de cuatro meses, por lo que cada participante tuvo veinte sesiones en una clase específica en la misma escuela. Todos los niños completaron los ocho juegos; sin embargo, hicieron un juego en cada sesión. Como se mencionó anteriormente, el procedimiento de aprendizaje se organizó en ocho actividades o juegos. Las actividades fueron diseñadas para combinar el modelo IPO y las propiedades de los juegos de aprendizaje. A lo largo de la etapa de entrada, el contenido instructivo está vinculado a las características del juego, que en conjunto contienen el material didáctico y el juego. Las principales características de nuestras ocho actividades se enumeran a continuación y se muestran en la Figura.2:

1. Capturar los peces. Un pez nadando en el mar y un número se muestran en la pantalla. Después de cinco segundos, el número desaparece, y los alumnos tienen que capturar tantos peces como el número mostrado. El concepto de número, el proceso de cálculo y la memoria de trabajo se estimulan porque hay que recordar el número original y el número de peces que capturan. Este juego se juega de forma individual. Figura. 1a. El resultado esperado de esta tarea es estimular la capacidad de los niños para calcular, utilizando la memoria de trabajo.

2. Ábaco. En la pantalla aparecen tres números (durante cinco segundos) y tres postes. El niño tiene que atrapar y localizar en cada poste un número de bolas igual al número sobre el poste. La estimulación se centra en el concepto de números de tres dígitos y la memoria de trabajo como en el caso anterior. Este juego también se juega de forma

individual. Figura. 1b. El resultado esperado de esta tarea es estimular la capacidad de los niños para recordar números de hasta tres dígitos.

3. La silla. La aplicación muestra una tabla con varias fotos de otros niños. La aplicación cambia la posición de dos fotos solamente, y el niño tiene que reubicarlas en la posición correcta. Se practicará la memoria de trabajo porque los niños tienen que operar con la ubicación correcta de los personajes. Este juego está diseñado para ser jugado en grupos pequeños de cinco jugadores. Figura. 1c. El resultado esperado de esta tarea es estimular la función ejecutiva de la memoria de trabajo.

4. La silla avanzada. Este juego es similar al anterior con la diferencia de que cada imagen cambia de posición en lugar de sólo dos. Figura. 1c. El resultado esperado de esta tarea es mejorar aún más la función ejecutiva de la memoria de trabajo mediante la inclusión de cinco imágenes en la tarea en lugar de dos.

5. Conteo por salto. Los niños tienen que calcular el número correcto en una secuencia. Los conceptos matemáticos de número y secuencia deben ser entendidos para poder elegir el correcto. Este juego también se juega de forma individual. Figura. 1d. El resultado esperado de esta tarea es también mejorar la función ejecutiva de la memoria de trabajo mediante la búsqueda del número que falta en una serie de cinco números.

6. Orden ascendente o descendente de los números. Se presenta una escalera con un número en cada escalón; el usuario tiene que igualar el número y el orden en una dirección ascendente o descendente. Este juego también se juega de forma individual. Figura. 1e. El resultado esperado de esta tarea es también estimular la capacidad de la función ejecutiva de la memoria de trabajo mediante la clasificación de una serie de cuatro números, ascendente o descendente.

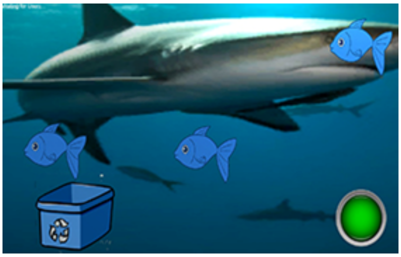
7. Dentro y fuera. Se muestra un conjunto de imágenes de diferentes elementos. Los niños tienen que decir si el objeto está dentro o fuera de la clase levantando la mano en un período de tiempo determinado. Se presenta el número de objetos elegidos en cada categoría. Este juego también se juega de forma individual. Figura. 1f. El resultado esperado de esta tarea es una doble prueba de la función ejecutiva de la memoria de trabajo mediante el reconocimiento de la ubicación de diez objetos y el uso de un gesto que se corresponde con cada ubicación.

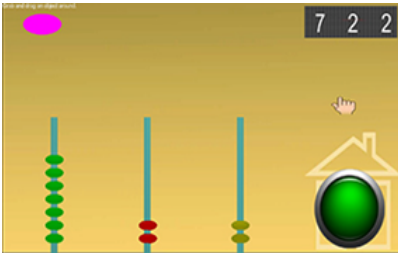
8. Buceo. Se presenta una escena submarina. Aparecen varios peces de diferentes colores, junto con un círculo de colores que muestra el color de los peces que deben ser capturados. El color del círculo puede cambiar durante el desarrollo de la tarea. Nos enfocamos en funciones ejecutivas. Este juego también se juega de forma individual. Figura. 1g. El resultado esperado de esta tarea es fomentar la memoria de trabajo haciendo coincidir el color del objeto visualizado con el color del objeto procesado.

La investigación, realizada en colaboración con el grupo GIPDAE de la Universidad de A Coruña, se desarrolló a partir de un diseño cuasi-experimental con pre-test y post-test, utilizando tanto un grupo experimental como uno de control a través de tres fases: la primera fue la evaluación previa de las habilidades del alumno; una segunda fase en la que se desarrolló el uso de la tecnología; y una fase final de evaluación. En las fases de evaluación, la memoria de trabajo se midió utilizando el Corsi Task, y las habilidades matemáticas básicas utilizando la prueba para el diagnóstico de competencias matemáticas básicas (TEDI-MATH). Esta parte de la evaluación de los diferentes juegos propuestos, así como gran parte de su diseño, ha sido realizada por el grupo GIPDAE.

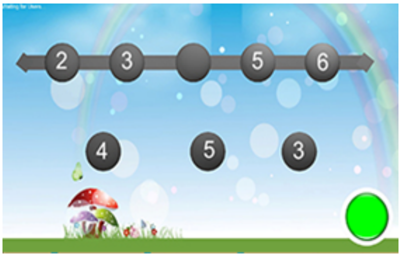
La principal contribución de este estudio es demostrar que en una etapa muy temprana de la infancia, se puede observar que las funciones ejecutivas, con un enfoque en la memoria de trabajo, pueden ser mejoradas e impactar positivamente las habilidades matemáticas desarrolladas a través de GIGL. Esta hipótesis fue probada experimentalmente por una prueba estándar, que muestra un aumento en las capacidades cognitivas de los niños a través del juego de ordenador. El conjunto de aplicaciones desarrolladas con el paradigma GIGL supera las limitaciones de las interfaces tradicionales utilizadas en la educación de la primera infancia, como el teclado, el ratón o el gamepad.

La integración de un dispositivo como Kinect en un motor gráfico como UNITY3D y un gestor de bases de datos ligero como MySQL nos ha permitido desarrollar un conjunto de 8 juegos educativos interactivos, que han sido validados por expertos en educación y nos han permitido trabajar con niños en edad preescolar en cuanto a funciones ejecutivas se refiere: memoria de trabajo, control inhibitorio y flexibilidad cognitiva





(a) (b)



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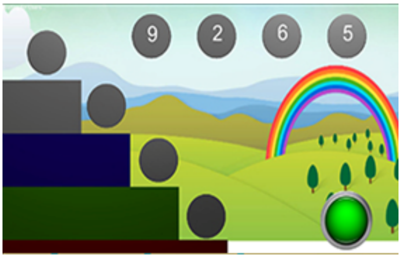

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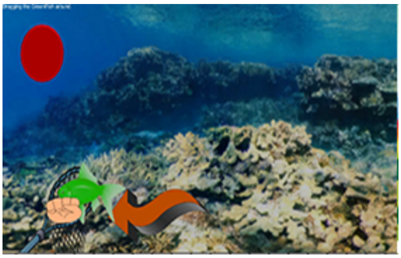

(g)

Figure 2: Interfaz gráfica de usuario del sistema basado en juegos.: (a) Captura de peces (b) Ábaco (c) La silla y la silla avanzada (d) Contar saltando (e) Número de pedido (f) Clase interior-exterior (g) Scuba diving.

Contents

Chapter 1

Introduction

1.1. Introduction

Human-Computer Interaction (HCI) is a research area focused on the communication paradigms between humans and technology, trying to understand the rules that a human use to communicate with computers.

During decades, the traditional way to input data in a computer has been the keyboard and mouse, and the feedback from the computer has been through the use of screens or printers. Nevertheless, in recent years, the videogame industry, searching of better experiences and emotions, has developed a set of new devices and technologies that allow users a more natural interaction than those provided by a game-pad, a keyboard or a mouse. These devices, such as Kinect, Wii mote or PlayStation Move Motion Controller, called generically "somatosensory devices", allow the tracking of the user body and hands position. These new devices allow to develop new interaction paradigms looking for more natural interaction and reducing the learning time, typically higher in other classic interfaces.

The new educational challenge involves engaging students, motivating their interests and keeping their attention [1]. Digital games can create active and attractive learning environments [2]. There is research indicating that digital games and education can go hand in hand and, in fact, we can already see examples of schools implementing the game-based learning in their curricula. Although many educational games are on the market, many still fail to reach adoption or success [3]. There are many factors to consider when designing an educational game, not just adding educational content.

Interactive media for education includes a variety of techniques, including simulations, games, hypertext, knowledge tools, tests, exercises, and web learning [4]. Among all the types of interactive multimedia available, our work focuses on the combination of digital games and natural interaction.

Digital games are attractive to teachers as additional media [5] because they promote a higher level of participation, enjoyment, and motivation [6]. In addition to the direct benefits related with motivation, games can promote attention and interest for the learning [7]. Games alone, rarely provide deep learning and are used primarily for memorization or for learning activities that have a real benefit in the real world [6, 8].

Modern electronic devices are present in our society and are increasingly replacing current media such as television or radio, promoting the need to foster graphics and visual literacy due to the rise of digital language [9]. The functionality of these devices, such as somatosensory device, [10] makes them a practical resource in many areas, especially regarding education, as they provide the necessary tools for the acquisition of diverse competencies [11]. The possibility of quickly accessing diverse sources of information, capturing, transforming or communicating data and ideas in various formats, turns Information and Communication Technologies, ICT, into a key vehicles to transform the classrooms into spaces for exploration and research, fostering an active attitude of the student in the development of significant learning [12] and representing a pedagogical aid of vital importance for the development of necessary competencies, such as those related to mathematics.

New society, which is based on information, communications and knowledge, requires a great ability to use electronic devices and media. Therefore, the early incorporation of ICT in the context of early childhood education becomes an essential resource from the standpoint of training competent citizens in a society that increasingly demands continuous learning. In this context, new interaction techniques provided by these new somatosensory devices, have done that digital game concepts have changed. And this has been used to develop new teaching models. In general, the main characteristics of the digital games called “serious games,” [13] are increasing the student’s motivation because they have been shown to be able to stay engaged over long periods. If the serious games include same kind of somatosensory devices is possible to incorporate the gesture recognition in their use, allowing a more natural and funny interaction.

These ideas, new paradigms of HCI, games and interaction devices, can be combined to develop applications generically called Gesture Interactive Game-based Learning (GIGL) [14], which seek to improve the performance of learning through interactive games.

These techniques are especially interesting in early childhood education for several reasons [15]; First, a significant shift in learning from a traditional educational model to a learner-centered model gives a more active role to the learner. Second, there is some empirical evidence that games can be useful tools to enhance learning and understand the complex subject. Thirdly, the attention of training professionals is the intensity of participation and interaction that computer games can do. But it is especially remarkable that these technological resources allow get feedback and supervision by teachers, in real time, while students are solving assigned tasks. Indeed, students can use their bodies to interact with the system, which will increase their motivation and physical activity. Many studies show that this kind of tool favors learning in different age ranges and increases motor abilities. However, there are other types of skills that should be encouraged to achieve overall education, especially in the first years of schooling. In this sense, the executive function includes a set of processes underlying the conscious and planned behavior directed to the objectives. They are associated with the response to new or difficult situations and the ability to inhibit behaviors that take us away from the objective pursued, through the deliberate control of thought, emotions and actions. As Carlson points out [16], executive functions refer to high-level self-regulatory cognitive processes that help in the supervision and control of thought and action. These skills include inhibitory control, planning, attentional flexibility, correction and detection of errors and resistance to interference.

The success in the implementation of these systems could be extended to people dealing with disabilities or specific learning difficulties, as autism, given good results and promising expectatives. Wainer and Ingersoll [17] point out, the use of technology to provide assistance is promising, especially when aimed at basic social communication deficits. In their study they review works that have used innovative technology, such as interactive computer programs and virtual reality, to offer a direct intervention focused on social and communication skills in people with Autism Spectrum Disorder (ASD).

According to Bölte, Golan, Goodwin, and Zwaigenbaum [18], technological advances can make it possible to develop more effective strategies to improve the quality of life of people with disabilities and their families. Among them would be the use of internet, online communities, robotics, alternative communication devices, computer-guided instruction, interactive metronomes, modeling through video, instruction through video, virtual reality, speech-generating devices, biological sensors, telecommunication, computer-based training (affectivity, social cognition, language) and computer games [19].

In this memory, we present a set of experiments which prove that executive functions, specifically working memory and basics mathematical skills, can be improved by using GIGL.

1.2. Objectives

The main objective of this thesis is to research about how a set of educational applications could allow teachers, to work in the improvement of the Executive Functions (EF) and Basic Mathematical Skills (BMS) in children of preschool. These educational objectives, improving EF and improving BMS, have been appointed by the collaboration between USC[1] -COGRADE group, where this thesis has been developed, and the UDC[2] - GIPDAE group.

This educational application would be based on the natural interaction between the children and the computers. It's here, in the interaction part of the work, where the HCI discipline takes hug importance for the achievement the success. And it will be developed through the recognition of gestures, using new somatosensory devices.

Specific objectives

1. Analyze different commercial tracking systems, that enable gesture recognition for arm and hand movements. It's expected that these systems use a somatosensory device focused on the children.

2. Development of a computerized educational application, as an experimental prototype, which will include new interaction paradigms and some educational games.

3. Design and develop a set of applications which allows an early stimulation of the Executive Functions and Basic Mathematical Skills.

4. Give the necessary technical support to the researchers of the GIPDAE group, for the real testing in a preschool.

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[2] University of A Coruña – Spain - Grupo de investigación en psicología del desarrollo y del aprendizaje escolar

1.3. Thesis Outline

This thesis is structured into seven chapters and additional appendices. Chapter two deals with the Human-Computer Interaction. The Human-Computer Interaction is a compound of many fields; each of them has a different characteristic which will be discussed individually. Then, we explain Usability and the interdisciplinarity of the HCI. The final section of this chapter will discuss the essential components of an interactive system will be presented: the human, the computer and the interaction.

In chapter three, we introduce the game-based learning. First, we discuss the definition of the GBL in general. Then, we explain what learning from the game is and describe the main games genres. finally, we will discuss the gesture learning and the technologies and application using the gesture. the types of devices for vision-based gesture detection and recognition system. Chapter Four presents by introducing the Executive function origins and the evolution of the concept to the present day. Following this, Executive functions and development of mathematical skills are discussed. The architecture of the system is outlined in Chapter 5. It describes how we use this hardware and software to construct the system. Then the chapter introduces the game content, interface, game logic and level settings of our educational game for pre-school children. Finally, a summary of the results and discussion is given in chapter 6 and the conclusion in chapter 7.

CHAPTER 2

HUMAN COMPUTER INTERACTION

2.1. Introduction

HCI is a discipline that is concerned with the design, evaluation ,and implementation of interactive computing systems for human use as well as the study of the phenomena surrounding this interaction [20]. This is the understanding and creation of software that people will want to use, will be able to use and will find effectively useful [21].

The development of computer systems for direct use means that designers must think not only about the capabilities of the system but also about the interaction that takes place between the user and the system itself. In a generic way, we can think in Computer Systems like tools designed to carry out a specific tasks, conducted by the commands (and data) given by a user. When this happens, there is an exchange of information between the human and the system and this is called interaction. The system interface must allow effective communication between the actors involved in the interaction (users and system).

One of the goals of the HCI is to improve the quality of the interaction between humans and systems. To achieve this, the knowledge that one has about the capacities and limitations of the human being must be applied systematically, together with the understanding of the capabilities and limitations of the devices and systems.

In recent years, the games industry, looking for more interactive experiences, has developed a set of new devices and technologies that provide users with a more natural interaction than a simple gamepad, keyboard, or mouse can. These devices, such as Kinect [22], or Wimote [23], allow tracking of the body and hands of the players, recognizing their movements and gestures, and enable a more natural interactive experience [24, 25].

Recently, all these ideas - new HCI paradigms, games, and new devices - have been combined to develop a set of applications generically called Gesture Interactive Game-Based Learning (GIGL), which aim at the improvement of learning performance through interactive games and gestures. GIGL opens new opportunities to learn complex contents by using new paradigms, for example, through body or hand movement, which provide a foundation for new learning models [26]. These techniques are especially interesting in primary and secondary education for several reasons. Firstly, more natural interfaces can be developed [27]. Secondly, learners can use their body as a tool; this will reduce physical passivity and increase their motivation [28]. Thirdly, the children can be supervised by teachers while they solve specific tasks, and feedback can be obtained for the system in real time [29]. Many studies report that GIGL can increase both the ability to learn [30, 31, 32] and motor skills in different ranges of ages [33, 14]. However, the overall education of children should stimulate other kinds of abilities rather than simply learning and motor competences.

2.2. Usability

Usability is an essential factor in determining whether educational software will facilitate knowledge acquisition. ISO 9241-11 [34] determines the usability of the product that can be used by specific users to achieve specific objectives with effectiveness, efficiency, and satisfaction in a particular context of use.

Usability is defined as the way to certify that a particular product fulfills the purpose for which it was created, is easy to manipulate and adapt to it without any complication and without the need to submit to an in-depth study of it. Jakob Nielsen and Loranger [35] define usability as an attribute of quality that is directly related to the ease of use of a product. Usability studies have focused on adult users. They have a clear ability to make monetary judgments when assessing a particular technique. In contrast, they have the ability to give specific details about the places they found to be defective in product tests. Thus facilitating the formulation of proposals to correct them.

The results of these studies have been of great importance for the good practices of HCI interface. But, after a while, it began to work with children as users, and this started a series of exceptions to the results obtained, since the behavior of these new users and the adults, is different.

The easy of learning can be measured by how quickly we perform a task, how many mistakes are made and the satisfaction of the people who use it. It also includes aspects such as being safe, useful and cost-effective.

General principles of usability

The most design rules are general principles, which can be applied to the design of an interactive system in order to encourage its usability. The principles are divided into the following categories [36]:

1. Ease of learning.

The ease which allows novice users to understand how to initially use an interactive system and, from this use, reach a level of knowledge and maximum performance use of the system. For the system to be easy to learn, it must be:

- **Synthesizable:** The user has to be able to evaluate the effect of previous operations in the current state. That is to say; when an operation changes some aspect of the previous state, it is essential that the user capture the change.
- **Familiar:** The new users of a system have a wide interactive experience with other systems. This experience is obtained through interaction in the real world and interaction with other computer systems. The familiarity of a system is the correlation that exists between the knowledge possessed by the user and the knowledge required for interaction in a new system.

2. Consistency

It relates to the likeness in behavior arising from similar situations or similar task objectives. The user relies on a consistent interface. However, the difficulty of dealing with consistency is that it can take many forms. Consistency is not a single property of an interactive system that is either satisfied or not satisfied. Instead, consistency must be applied relative to something. Thus we have consistency in command naming or consistency in commands.
We can say that a system is consistent if all the system is always used in the same way, as long as they are used and no matter when it is done. Recommendations to design consistent systems:

– Follow style guides whenever possible.

– Do not make modifications if it is not necessary to do them.

– Add new techniques to the pre-existing set, instead of changing the ones already known.

3. Recoverability

The degree of ease that an application allows the user to correct an action once an error is recognized. There are two instructions in which recovery can occur, forward or backward. Recovery for forwarding errors includes accepting the current state and negotiating that situation towards the required state. Recovering the error back is an attempt to undo the effects of the previous interaction to return to a previous state before proceeding.

4. Response time

The response measures the total time it takes from the time the user requests to receive a response. It is essential that the response times be possible for the user. In general, short periods and immediate response times are recommended. Instant means that the user realizes the system feedback immediately. However, even in cases where an immediate response cannot be obtained, there must be some indication to the user that the system has received a request for action and is responding.

The HCI process by which information flows between the computer and its user is defined as a loop of interaction. This loop of interaction has several phases [37], and a description of each phase is given below:

– Visual Interaction: The human-computer interaction is developed based on visual communication, this is probably the most widespread area in Human-Computer Interaction (HCI) research.

– Audio Interaction: The interaction is based on audio features whereby the required information is exchanged through different audio signals.

– The environment surrounding the task: Surrounding conditions should be considered prior to setting the goals from the interaction.

– The available logistics: The environment that the computer is connected to.

– Channels of interfacing: To ensure the no-overlap between processes the human and computer not pertaining to their interaction.

– The flow in channel: Information flows starting from the surrounding to complete the required task that the user set using the computer.

– The Output (product): Information that flows from the environment which surrounds the setup and machines.

– The Feedback process: It is the cycle through which the interface evaluates and then facilitates the process completion ending in confirming the transfer of these process from the human to the computer and back through the interface.

– Best Fit: Matching between the user and the task of the computer design, in order to maximize the number of accomplished tasks by the available human resources.

2.3. The interdisciplinarity of the HCI

HCI has become an umbrella term for a number of disciplines [36]. HCI can be used in all disciplines wherever there is a possibility of computer installation. Some of the areas where HCI can be implemented with distinctive importance are mentioned below :

1. Sociology

Study human behavior as a member of a social group. They study qualitatively or quantitatively (by means of surveys or interviews) the attitude of a person or a group of people towards some product or task. It allows the results to be extrapolated to adapt an interface to a social group.

2. Psychology

Studies an individual's behavior and states of consciousness. In the HCI it is possible to study the way in which individuals perceive objects and process the information they receive. It makes it possible to evaluate and determine the degree of satisfaction of the interfaces. It is used in the phases of Analysis of requirements to know the mental model of the individuals, that is to say how they perceive the task that has to be carried out. And it is also used in design to capture that mental model in the system, for example using appropriate metaphors.

3. Ergonomics

Studies the conditions of reciprocal adaptation of the person with their activity and the tools they use. Ergonomics studies the physical characteristics of interaction: work environment, environmental conditions, physical characteristics of interaction mechanisms. It allows studying the organization of controls and screens, the use of colors, health aspects that affect the quality of the interaction and the restrictions of users and the physical environment of the interaction. It is used in the Analysis of requirements phases, through the study of the interaction environment; in the design phase, to decide the organization of controls and screens, colors, etc. And in the launch, to evaluate whether ergonomic rules have been complied with and to adapt to unforeseen events.

4. Graphic design

Graphic design is used in the creation of "beautiful and useful" objects and in the conception of an object destined for mass production. A good graphic design of screens, icons, etc., will obtain interfaces that will not produce a rejection to the user at the same time that will facilitate the interpretation of the actions to be carried out. It is used in the Design phases as it has to provide the user with the visualization of the elements proposed for the design of the system; by establishing the appearance of the metaphors used, the graphic style of the application, its consistency with the corporate image of the company, etc.

5. Program

Establishes the actions to be performed by the system when the user interacts on the interface. Currently, it is normally done with event-driven languages that use the paradigm of object-oriented programming (Java, .NET languages such as C# or VB.NET, etc.). Programming is used in the design phases, for the production of prototypes with limited functionality that can be used for the evaluation of the interface; and in the implementation and launch, as these are the phases in which the system is provided with complete functionality.

6. Software engineering

Studies software development techniques based on methods taken from engineering. It specifies the requirements of the analysis phase and the different functional elements of the system. It materializes the technical specifications and gives the guidelines for the codification of each one of the parts. The software engineer oversees the entire development process.

7. Artificial Intelligence

Used in the design of programs that simulate the behavior of human intelligence involving tutorials, assistants, expert systems, speech-controlled interfaces. It is used in all phases, whenever the system requires these functionalities.

8. Design

For systems to be widely accepted and used effectively is that they are well designed. This does not mean that all systems must be designed to adapt to each user, but that systems must be designed for the needs and capabilities of the people for whom they are intended.

The design is now known to be a great challenge, partly because of the rapid change in the underlying technology, partly because of conflicts and trade-off between design objectives.

In summary, the great challenges faced by HCI designers are: to keep abreast of changes in technology and to ensure that designs offer good HCI as well. Generally, to achieve a good design, each control must have a clear functionality and reflect the effect it produces. If there are ambiguities, it is no longer understandable. The controls must necessarily be visible, with a good mapping to their effects, and its design should always suggest its functionality.

In summary, the aspects to achieve a good HCI design:

- Knowledge of human goals, capabilities, and limits.
- Knowledge of the functionality of the system.
- Knowledge of the social, physical and organizational aspects of the environment work.
- Knowledge of the capabilities and limits of computers
- Feasibility study.

2.4. HCI Components

When designing the HCI for computer systems, it is necessary to take into account the four main elements: users, system functionality, work environment, and technology. The user developer will be in charge of establishing the links between the components.

Both the designer and the users are the main protagonists of the design process. The designer must:

- select the most appropriate input and output devices for the task(s) to be modeled and decide which is the best style of interaction to design the user interface (UI);
- understand human psychology and the particular characteristics of users;
- know the model that people have of themselves, of others, of the environment and of the things with which they interact, and that help them know what to do and how to react to current and future situations (mental model);
- moreover, take into account the environment in which the system will be used, such as space and light, social and organizational aspects.

System Functionality

It is necessary for designers to establish precisely the function that the system will perform, taking into account the tasks or activities that users perform, to achieve the efficient design of the system and the restrictions under which the system must operate to ensure the construction of a correct system.

Because when creating a product, both users and designers have their ideas of what the product should do and an individual way of perceiving the world, it is the fundamental task of the designer to combine the different mental models to determine the correct functionality of the product System.

Work Environment

In order to design an appropriate HCI, it is necessary to carry out a study of the environment in which the computerized system is going to operate, taking into account three aspects: organizational, physical and social. The importance of taking into account these three aspects lies in the fact that they allow determining certain characteristics of the user interfaces, the distribution of space and location of office equipment and material, the distribution of work and the assignment of responsibilities.

Technology

From the point of view of technology, it is necessary to determine the appropriate input and output devices (hardware elements) for the interaction, as well as the availability or possibility of acquiring them within the organization.

The input has to deal with recording and entering data into the system and issuing instructions to the computer. In order to interact effectively with systems, users must be able to communicate their intentions in such a way that the machine can interpret them. Therefore, we can define an input device as a device that, along with the appropriate software, transforms user information into data or commands, that computer applications can process.

Output devices are those that convert information from a computer system into something that a human being can perceive, known as an output. Most computer outputs are visuals (in two dimensions) and sonorous. The designers felt that a more significant effort should be made to generate outputs in a way that takes into account the needs of people with disabilities. A large number of people have limitations such as blindness, color blindness, visual impairment, or hearing problems that make it difficult to interact with the output.

Visual Output

The visual presentation of texts or information is the most common form of output. In terms of visual presentation, three aspects related to user needs are essential: physical aspects of perception (brightness, color combination, etc.), the way the information is displayed (text size, the order of items, etc.) and the way the information is used.

Sound Output

Although the common uses of sound in the interface are largely for feedback and alerting purposes, they also allow impressive sound effects to be achieved in games and advances in technology result in high quality and increasingly realistic sound. The sound has an important value when the eyes are busy with some other task, or when a situation of interest cannot be fully visualized. The different types of sound include:

– Speech: A more natural way of providing information about what is happening in the systems to users.

– Music: clock bells, tunes, church bells, alarms, shouts of street vendors.

– Natural: it is used in computer interfaces because the human ear can extract a large amount of information without effort, being accustomed to it. For example whispers, blows, scratches, tinkles, crackles and echoes.

Some researchers such as Buxton [38] suggested that sound is used to provide more information about what is happening in the system. In other words, systems benefit from the use of sounds by directly mapping the processes they represent. Since we have a highly evolved hearing system capable of generating detailed information about the environment, we must use this potential to improve interfaces. Buxton and others argued that soft sounds are not perceived as intrusive if their use is well designed and provides useful information.

The following considerations must be taken into account when selecting the appropriate devices for interaction with a computer system:

– Help the user to perform his tasks in a safe, effective, efficient and enjoyable manner.

– Determine the particular manipulations that must be carried out to perform the required tasks.

– Establish a natural correspondence between the way the device is manipulated, the feedback given by the system and the meaning of the result regarding the user's mental model.

Users

A fundamental theme for the HCI, related to users, is to understand their physical, intellectual and personality aspects. Getting to know them and understanding how they will use the system becomes something fundamental that will generate a design that will later translate into an operating system that will be efficient and usable.

In order to identify the characteristics of the user population of the system, an analysis must be carried out, so it must be done:

– Identify all users of the system.

– Classify users according to their characteristics.

– To construct the profile of the users, trying to identify what is common and not common to all of them.

When creating the design, it is important to emphasize that the human being has a limited capacity to process information. We can communicate through four input/output channels:

- Vision.
- Hearing.
- Touch.
- Movement.

Chapter 3

Computer Game-Based Learning

3.1. Game Based Learning

The use of games as learning enhancers in schools has expanded in last decade [39]. Games permit students to share their knowledge and contribute to the teaching and learning process.Driving a new trend where users become preparer of their Learning environments based on Game-Based Learning (GBL) [40].

Numerous researches underline the successful results derived from innovative educational practices mediated by games. Bottino et al.[41] analyse the positive impact on the reasoning capacity of schoolchildren in early childhood education. Zhao and Linaza [42] observe the development of complex capacities such as leadership or cooperation through the use of video games in primary schoolchildren.

Tüzün el al. [43] highlights the increased motivation of primary school students to learn geography linked to the play scenario they recreated to contextualize learning. Evans [44] highlights that performance in mathematics and science improves significantly. Meanwhile, Squire and Jan [45] demonstrate that certain video games activate skills related to scientific argumentation for the resolution of riddles.

Papastergiou's [46] experience with digital games in secondary education, underscores their potential as catalysts for learning and motivation. Annetta et al. [47] highlight how video games increase students involvement in homework. The adoption of a GBL methodology based entirely on the use of digital games, serious games or video games is presented as a disruptive educational practice, which takes advantage of the intrinsic motivating effect of certain video games to capture the attention of learners.

The mechanics and dynamics of the game are used to immerse them in attractive tasks that facilitate learning, reducing the level of difficulty [48]. Some researchers [49, 50, 51, 52, 53] assert that this innovative methodology can boost training processes, encouraging students to acquire learning in a motivating way. In the international context, there are experiences in school environments that have opted for this methodology, using serious games or digital games to promote the development and acquisition of basic skills and competences [54].

The transfer of game scenarios to video game screens has implied new educational opportunities [55], giving rise to didactic strategies focused on the use of video games in the classroom.. However, Learning based on Games offers a further step as an innovative methodology that takes advantage of the educational potential presented by video games, serious games or digital games to promote any training process, encouraging users to acquire learning in a motivating way, involving them and giving them a more active role [56], using them as tools to activate skills and acquire knowledge. It is evident that this GBL methodology rescues the social component of the game to enhance social skills, cultural and social values [57], in addition to developing critical thinking. Undoubtedly, the interaction with a video game allows the player to control both the characters and the situations that are simulated, being immersed in a virtual world similar to the real one. However, in order to be active and to take full advantage of its potential, a previous selection of suitable video games or serious games is required, designed with the intended educational purpose. These virtual worlds activate strategies for solving problems different from those used in conventional schools [58], offering creative formulas to tackle new challenges such as the development of Multiple Intelligences [59].

3.2. Computer and Learning

Recently, the interest in technologies related to computer game-based learning increased. Several factors such as the shift from classical and traditional educational into learner-oriented, efficient learning module, and also taking advantage of available resources like the easy-to-use produced games and the increasing demand for using games can as an effective tool for teaching and self-learning, in which students will be motivated to participate and engage in the education process [15].

The reviewed literature concerning the game-based learning of both children and adults concluded that the rationale behind using games in learning is related to the fact that games motivate their users, examples of this literature were given in Grice and Strianese [60] and

Dempsey [61] provides examples of the application in which computer games were used within the educational tasks and identified the GBL as “a set of activities involving one or more players. It has goals, constraints, payoffs, and consequences. A game is rule-guided and artificial in some respects. Finally, a game involves some aspect of competition, even if that competition is with oneself”.

The vast majority of reported studies concerning games to motivate individuals who participate in these gaming studies were conducted to assess the increase in motivating a population of these studies which was mainly children; such population is excited by nature to practice games whether in the physical or electronic formats of these games. Scaling up these results to adult populations seems to be an assumption. Computer game-based learning is still a persuasive argument for using games in educating for beginner learners in spite of its potential aspects to motivate advanced learners and to compel the rationale for their use in education.

Prensky [62] reported a clear distinction between digital natives learners or game generation learners, Prensky studied the impact of computer games, television programs, and other media resources on intuitive learning for both young and adults. The young ones grew up using these technologies whereas the older learners use these technologies with much conscious effort and they were exhibiting a traditional learning scheme. Prensky also discussed the difference in cognitive skills for those grew up using computers and technologies when compared with those who immersed with using technologies in the sense of acquiring and assimilating information. He then summarized these cognitive changes into the followings:

- Games Generation learners (GGL) were found to process information in much faster rhythm.
- GGL can process information from multi sources at a time.
- GGL focus on charts, figures, and graphics before written materials.
- GGL don’t follow a certain linear approach when it comes to learning materials, but often they follow a hypertextual route which can be quite random.
- GGL prefer working in groups rather than being a sole worker.
- GGL lean to have a more active role when seeking knowledge or further information to help them in the educational process.

– GGL is less distinctive between gaming and work objectives. So, the educational games will be sees as an obstacle to them.

– GGL tends to expect an immediate reward and instant feedback, having no quick action might demotivate them.

– GGL is more adaptable to new concepts and in particular those fantasy concepts. Likewise, they are more adaptable to new technologies.

Video games also can be used for education based on their embedded advantageous learning principles [56]; the argument was based on learning new knowledge through playing video games regardless if these games are not quite appropriate for teaching. The contents of video games will improve the learner's skills on how to interact with new technology and transfer much of these skills to learners. These gained skills assist in socializing with new groups and build on that for subsequent learning in other fields.

Other advantages for the game education packages through using computer were also reported in the literature and includes the ability to improve the learner's practical skills in conducting the root cause analysis, increase the level of their motivation and retention period to learn [63] and the games ability to enhance learners through adjusting these games and classify them into different levels starting from beginner into advanced user to best suit the skill level of users [64].

Gee [56] proved that the active, and most meaningful learning usually starts at the learner's side then to the designers, to extend the game including the comments and feedback from the players.

Several studies [46, 65, 66, 67] provide an overview and evidence of learning through both non-computer games and computer games . Sun [68] describes developed games to learn through a role-playing technique in which the focus will be on basic principles for operation management. The technique was then evaluated by a group of researchers trying to describe the outcomes of that exercise in which the participants were involved.

Further on, studies concerning a comparison of learning satisfaction and its effectiveness between the game-based learning and classical one through conducting a pre and posttests to evaluate the efficiency of the learning process in medical environments, and the level of satisfaction at the learners end, the outcomes of this study proved that there was no significant difference in between the two groups, yet the group that used games were more satisfied [69].

Other study focused on the ability of school students aged from 4-5 to examine the impact of game-based learning technologies in regards of the relative effectiveness of two software applications concerning their ability in understanding classifying the different types of taxonomy [70]. The team of researchers examined 59 children and concluded that the use of game-based education helped in increasing the participant's ability to identify and classify the different taxonomical characteristics.

Game-based learning has also been enhancing the learning process within the multi-discipline cross-linked sciences. Magnussen [71] in his study which was based on observations and resulted in evidence base that collaborative learning from the game increased the ability of school kids to respond to the large volume of data at a time and then establish conclusions based on these data sets. Evidence was also presented by Squire et al. [72] for teaching social sciences through the computer-based games, a study conducted on 18 High School students confirmed that with a proper introduction to the objective, the students exhibited fast learning of history case studied.

The 3-D virtual games were proved to be essential for promoting collaboration within postgraduate students [73], the study revealed that the 24 postgraduate students who played the game demonstrated effective collaborative teamwork during the evaluation that took place pre and posttest including the efficient negotiation skills and the high coordination between the participant to exchange information.

Educating adults using computer game-based programs contributed to increase learning in adult groups when they play games for a period of 60 minutes or more [74], this experiment did not account for a control group even those the participants were 30 adults divided into 3 groups, therefore it is impossible to draw a conclusion on whether the computer game-based programs were the most effective in educating information systems to adults.

Simulated games have been known as a supportive tool for education and teaching; the potentially will incur a revolution in the teaching field [75, 76]. Game-based education offers virtual environments that build the learners' ability to solve problems and stimulate their competencies to initiate critical thinking. These games offer a potential tool for social and cultural education environment as concluded by [46, 75, 77] in their research-based using educational games. Moreover, these games are beneficial to educate both children and adults as reported by [78] in their comparative studies to test both age groups and their reaction to using educational games.

These game-based education tools can be useful to improve the player's behavior, a study by Gustafsson and Bang [79] introduced a mobile-based game called 'Power Agent' that meant to teach young students, teenagers and their respected families to induce the behavioral change in respect of conserving the use of energy within their houses. The developed teaching game provided intuitive showcase on best energy management practices and resulted in engaging participants and stimulating the energy saving initiatives afterward.

Game-based learning demonstrated other advantages such as those to develop logical thinking in order to solve mathematical exercises. Eagle [80] designed a 2D role-playing game called 'Wu's Castle,' which enables students to develop C++ code to be used in the problem-solving game.

Another fact stipulated by research outcomes, concerning the advantage of using educational games, is related to its ability to motivate players into learning while playing, games were found to be influential in retaining the player's attention and maintain their engagement in the game phases as described by the literature concerning the enhanced instructional design model in which they outlined the criteria for creating meaningful learning experiences. They also explained what would be the common principles that define compelling learning experiences and then how to explore the different levels of games and learning from small-scale scenarios, through to contingent and full engine-driven scenarios [56, 81, 82, 83, 84]. Moreover, the games contributed to building self-learning skills to players [85, 86] as these software's provide instant feedback [81, 82, 83, 84, 87] which helps players to develop their perception on the way forward with the learning tasks.

Garris [15] proposed the input process outcome model (IPO), which has been adopted as a tacit paradigm for most studies on learning games. The IPO model delimits three elements: (1) the input, which illustrates the design of the instructional process; (2) the process, which introduces the cycle of the game and allows for the user's feedback on their experiences; and (3) the outcome, through which thorough analysis of training objectives and outcomes is made. Figure.3.1 illustrates this process. The IPO paradigm has been applied successfully for several research projects; for example, Lu et al.[88] used this model to improve children's proficiency in the English language, Ghergulescu and Muntean[89] introduced a motivation assessment-oriented IPO game model to create an educational game. Taking into account the playful nature of children, we have adopted the IPO model to the design and implementation of a gesture-based learning application in order to show that processes that underline conscious skills, such as working memory, can be reinforced.

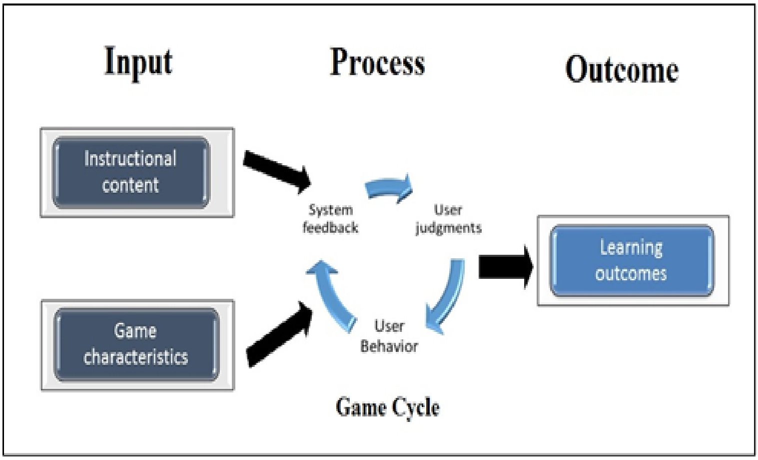

Figure 3.1: IPO game-based learning model [15].

To achieve this cycle and allow effective learning, Garris analyzes the factors that characterize the games and defines six major dimensions as presented below:

- **Fantasy:** to unfold an imaginary context of both environment and characters.
- **Rules and objectives:** both must be clearly defined so that the player understands his progress, receiving the appropriate feedback.
- **Sensory stimuli:** to present visual and auditory stimuli that accompany the "drama" of the context of the game.
- **Challenges:** to contain an adequate difficulty that encourages the player to advance.
- **Mystery:** define a certain level of complexity and format in the information presented to the student to keep him interested.
- **Control:** to allow active control of the player.

3.3. Gesture Learning

Gestures are significant and expressive body movements involving physical movements of fingers, hands, arms, head or face. These gestures try to translate the user's information for the computer and, thus, interact with the environment. A gesture can also be seen as a compression of information for transmission that will be reconstructed by the recipient later on. Gesture recognition has a wide diversity of applications [90], such as:

1. Interaction with the computer.
2. Assistance for disabled people.
3. To have children interact with computers.
4. Patient monitoring.
5. Navigation and/or manipulation in virtual environments.
6. Assistance / E-learning.

In general, gesture recognition is particularly complicated because gestures are often expressed ambiguously and incompletely, and the same concept can be expressed in different ways by different users or even by the same person in different situations.

3.3.1. Gesture Interface Technologies and Applications.

Researchers have been developing diverse technologies, applications, and algorithms for gesture recognition in order to advance using image sensors and cameras to generate data and represent three-dimensional space around the device and transform this data into meaningful operations.

Technology

There are several potential devices which utilize interfaces such as, smartphones, laptops, games consoles, and television. However, scientists attempt to further develop the touchless technology being commonly used in gaming software. However, these technologies offer a great potential to be used in other fields including, automotive and healthcare industries. The two most common technological approaches for capturing finger and hand positions for gesture recognition are: a) wearable devices, especially gloves, and b) vision-based approaches.

The wearable devices use mechanical or optical sensors to detect body part movements and positions. The most common format is to attach the sensors to a glove [91]. Other approaches include a wristband and pad [92], a tiny projector and cameras coupled to a pendant [93]. Often a tracking system is integrated to measure the position and orientation of the hand(s). The tracking technologies used for this purpose include magnetic,[94] inertial, and ultrasonic systems. The best data glove systems can provide accurate measurements of hand pose and movement. Unfortunately, they also require user-specific calibration, they restrict the naturalness and ease of interaction, and they are often expensive.

Forcing users to wear a device is an important limitation. Users resist wearing tracking devices and computer-bound gloves because it restricts the user's freedom-of-movement and it takes time to do and removes. Vision-based gesture recognition relies on video images, avoiding the need to physically restrict the user's freedom-of-movement. Starner and Pentland [95][65] demonstrated that one camera is sufficient to effectively and accurately recognize hand posture and gestures. However, in order to track hand movement in three dimensions, two or more cameras are needed. Although multiple cameras are more complicated to integrate than a single camera, the extra information is essential when three-dimensional information is required as described by scientists in their attempts to explore the potential use of augmented reality on mobile phones. Users have to not only create, but also to access then modify, and annotated virtual objects in order to relate them back to the real world by manipulations in 3D [96, 97, 98, 99, 100].

There are situations where RGB images cannot provide sufficient information for effective gesture recognition. For example, images captured in dim or unpredictable lighting can be difficult to segment. Skin-colored objects in the scene can also interfere with the segmentation and recognition of hand gesture. Depth images provide an excellent alternative in these situations because they are less likely to be affected by lighting conditions or colors Figure.3.2 Kinect, Microsoft's low-cost depth sensor, uses this approach and has enjoyed considerable attention within the gesture recognition community [101, 102, 103, 104].

Applications

Various researchers have proposed hand gestures as substitutes for traditional input methods (e.g., using a mouse as a pointing device). For example, Quek's Finger Mouse [98] recognizes two-dimensional finger movements as input to the desktop and Crowley et al.'s

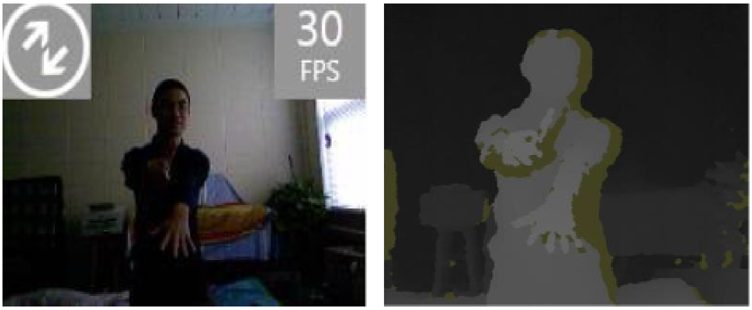

Figure 3.2: RGB and Depth image in limited lighting condition. Left-RGB image, Right-depth image.

Finger Paint [105] enables a user to “draw” in a projected image. Other researchers have applied gesture interfaces to specific applications or fields.

Wachs et al. [99] describe a hand-gesture-tracking device called Gestix that allows surgeons to browse MRI images in a sterile environment within the operating room. Nickel and Stiefelhagen [97] test a real-time system for human-robot interaction to detect pointing gestures and to estimate pointing directions. Trigueiros, et al. [106]use a Kinect to remotely navigate a robot. Riener et al. [103] use gestures to read, browse, search, or delete emails while driving. Wilson [107] turns tabletops into touchscreen devices with a downward-looking Kinect sensor. Cabral et al. [96] build a virtual reality environment in which gestures are used for three-dimensional navigation or visualization.

Suarez and Murphy [108] survey 37 papers that involve hand gesture recognition with depth images. The variety of applications and interfaces is still limited. Twenty-four of thirty-seven papers include real-world applications but are mainly for testing their hand localization and gesture classification algorithms.

People with disabilities can benefit greatly from HCI technologies [109]. Simpson et al.[110] propose a component-based smart wheelchair system and discuss other approaches that integrate various types of sensors (not only vision). Kuno et al.[83] also present a wheelchair navigation system. Duchowski [111], used computer vision to interpret facial gestures for wheelchair navigation. Patrick and Pun [112] introduce a system for presenting digital pictures non-visually (multimodal output), and the techniques in [113] can be used for interaction using only eye blinks and eyebrow movements. Some of the approaches in other application areas such as which Brewster used [114] could also be beneficial for people with disabilities HCI has great potential in making computers and other resources accessible to people with disabilities.

Other applications include biometrics [115], surveillance, remote collaboration [116], gaming and entertainment [117], education, and robotics ([118] gives a comprehensive review of socially active robots). HCI can also play an important role in safety-critical applications (e.g., medicine, military [119, 120]) and in situations in which a lot of information from multiple sources has to be viewed in short periods of time.

3.3.2. Devices for gesture detection and recognition system

The main approaches to gesture recognition are related to the following types of devices:

– Non-vision-based devices: Tracking devices, instrumented gloves, bracelets, among others.

– Vision-based devices: Using one or more cameras.

- Devices not based on vision.

These types of devices have non-vision-based sensors and use various technologies to detect motion, such as accelerometers, multi-touch displays, electromyographic sensors, and others, which include different types of detectors. There are several categories within this type of device:

Wearables: These types of devices have the shape of a garment, which includes the sensors necessary to know the disposition and movements of the examined part of the body. They are usually gloves, bracelets or a whole set, and are used for virtual reality environments. They are equipped with special technology capable of detecting finger flexion and often have the ability to capture information about the position and rotation of the glove. An example is the CyberGlove device, shown in Figure.3.3 which was used in the system developed in [121] and recognizes multidimensional gestures using a condensation-based trajectory search algorithm. These devices are often related to biomechanical and inertial technologies.

An important aspect in recognition of gestures from this type of device is that the gestures are seen as a successive sequence of fixed postures. These postures are composed of finger flexion values, hand orientation data, and an additional value indicating the relevance of the orientation for a particular posture.

Figure 3.3: RCyberGlove From http://www.cyberglovesystems.com/.

Biomechanical: Devices that use biomechanical techniques such as electromyography to measure gesture parameters. The project developed in [122] for the Real Time Bio signal Interfacing based on electromyographic sensors and the Myo bracelet Figure.3.4, which detects gestures and movements also using electromyographic sensors, are examples of this type of devices.

Figure 3.4: MYO bracelet. From https://www.myo.com/

Inertial: These devices measure the variation of the earth's magnetic field in order to detect movement. Accelerometers [123] and gyroscopes [124] are used for the measurements. These are inertial measurement systems responsible for estimating the acceleration from the displacement suffered by a mass contained within the sensor. An example of controllers with accelerometers in the world of video games is the one developed by Nintendo, called Wiimote for the Nintendo Wii console, which can be seen in Figure.3.5. In addition to providing information about acceleration, it contains an optical sensor that can determine the direction where it is pointing within the detection field. This type of device works with temporal and spatial data. The temporal data indicate at what moment of time the information is being delivered. The spatial data provide the controller acceleration information on each coordinate axis (x, y, z). In order to find some valid meaning to these input vectors, it is necessary to use some procedure that allows to interpret and to find patterns for the recognition of gestures.

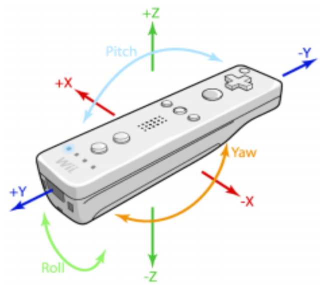

Figure 3.5: Inertial device: Wiimote.

Haptics: This group includes devices based on various types of touch screens. For example, in [125] a module was developed for the recognition of dynamic gestures on multi-touch screens. Figure.3.6 shows some gestures that can be interpreted by a multi-touch screen.

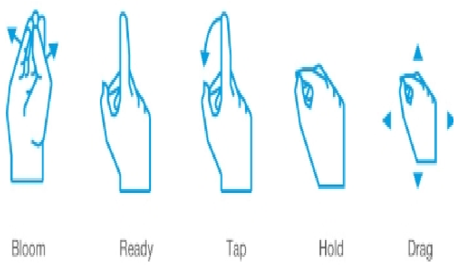

Figure 3.6: Gestures interpretable by a multi-touch screen.

- Vision-based devices

Devices with vision-based sensors include one or more cameras and provide data processed from captured video sequences. The processing of each frame is based on the filtering, analysis, and interpretation of the data. The following types of vision-based technologies can be distinguished [126]:

Typical webcam : Gesture recognition techniques based on data derived from a monocular camera, using detection methods from color, shape or learning techniques with pixel values Figure.3.7.

Figure 3.7: Webcam.

Stereo camera: Techniques based on images captured from two cameras, which provide from the recorded data an approximation to a representation of a 3D model Figure.3.8.

Figure 3.8: Stereo camera.

Active techniques: Techniques that require the projection of some type of structured light. Kinect and Leap Motion in Figure.3.9 are examples of this type [127].

Figure 3.9: Leap motion controller.

Kinect :a new development in consumer sensing technology is the Microsoft Kinect sensor [22]. allow tracking of the body and hands of the players, recognizing their movements and gestures, and enable a more natural interactive experience [24, 25]. However, the properties of data captured by Kinect have attracted the attention of researchers from other fields [107, 128, 129, 130, 131] including mapping and 3D modeling [132]. More details about Kinect in appendix 1.

Figure 3.10: kinect.

Kinect features an RGB camera, a depth sensor, a multi-array microphone and a custom processor that runs the software patented, which provides full body motion capture in 3D, facial recognition and voice recognition capabilities. The Kinect microphone allows you to carry out the source location and the suppression of environmental noise. The camera has two types of resolution (320×240 and 640×480, both high color) and sends data with a refresh rate of 30 fps.

Invasive techniques: Systems that require the use of body markers such as color gloves [133] or LED lights (PlayStation Move Controller) Figure.3.11.

Figure 3.11: : PlayStation Move Controller.

3.3.3. The development of Gesture User Interface (GUI)

The user interface is considered the most important aspect because for many users the interface itself is the system. It is the part of the system that we can see, hear, interact with, and in some cases even touch. Any other aspect of the software is hidden behind the interface, be it a monitor, a keyboard, a mouse, or any other hardware used to interact with the system [134]. The objectives to look for when modeling a good user interface are simple: Get the user to work with the computer or system in a simple, productive, and in some cases, entertaining way.

With these ideas in mind, a user interface is defined as the physical parts of a computer, as well as its software, that a user will be able to see, hear, understand, interact and direct. A user interface consists of two components: Input components and output components. The input is defined as the way a person communicates their needs and wishes to the machine. Typical input components of any computer today are the keyboard, the mouse, and in cases of touch devices, the hand itself.

The output is defined as the way in which the system provides the user with the results of its calculations and operations performed, according to the user's requests. The basic output mechanism of any computer today is the screen, followed by the devices that take advantage of the user's auditory abilities: voice and sound. Thus, a good user interface should provide good input and output mechanisms so that all the user's needs can be met, taking into account their capabilities and limitations, in the most efficient way possible. A great interface will be what makes the user forget about it so that the user can focus on the task at hand rather than on the mechanisms that present the information or how to perform the task.

It is very important to understand the importance of user interfaces. First, for many users, the interface itself is the system, as it is the only visible and tangible aspect of the application they are working with. Second, because it is the only way in which an application shows the results obtained to the user, results that, for many organizations, are of vital importance for the productivity of that organization. A bad interface could cause, in extreme cases, compromise the safety of its users or the general public (Application in a hospital, or in a power plant).

To-date, using gesture to interact with computer received high attention. Bhuiyan and Picking reviewed literature GUI for over 30 years, and surveyed researches used the various types of gesture, interface, technology, and the user groups [135]. They review concluded that the most difficult technology like sensor, gloves used at the beginning was advanced to webcam and image processing. Easing of use technology, affordability and familiarity enabled GUI to provide a new horizon for even children to interact with new technology.

Multimedia and communication systems go towards everywhere computing and towares hand free interaction between users and machines [136]. Accordingly within, these features of gesture interfaces can be used in great various fields, e.g., in entertainment, education, and aiding people with disabilities.

Chapter 4

Executive Function

4.1. Executive Function

There is no overall agreement on how to define executive functioning, but most authors agree that it refers to top-down control processes that are involved in regulating action. Executive functions include the set of processes that underline conscious and planned behavior directed to goals. They are associated with responding to new or difficult situations and the ability to inhibit the behaviors that move us away from the objective pursued, through the deliberate control of thought, emotions, and actions [137]. As Carlson [16] notes, executive functions refer to high level self-regulatory cognitive processes that help in the supervision and control of thinking and action. These abilities include inhibitory control, planning, attentional flexibility, error correction, detection, and resistance to interference [16]. For these reasons, these skills are important for initial learning in kindergarten.

Executive functions are basic skills for gaming; players need to be able to navigate the game, remember a map, and focus on goal-relevant information while blocking out irrelevant memories and constructing a mental representation of the problem to be solved. Through deductive thinking and experimenting with potential solutions, users learn how the system works and how to solve the problem. This process requires players to retain vast amounts of information for navigation, representation-constructing, and solution-testing. The information is processed by an individual continuously drawing upon their limited pool(s) of working memory to temporarily store information and to direct their attention [138, 139]. The amount of working memory involved in a task and how many is allocated is determined by media features and user characteristics [140].

From an attention control perspective, gaming ability expertise may have a positive impact by helping individuals to identify which information elements are relevant to certain goals, and which data to block out. A learner's gaming skill expertise is also a critical factor in searching for object-relevant details to concentrate attention on [140, 141]. Therefore, players with better executive skills will be more capable of maintaining attention to achieve the purpose.

Although individuals are not born with a high degree of executive function skills, they have the potential to develop them [142]. However, the process of acquiring these functions takes a long time, beginning in infancy and continuing into early adulthood, and after that, is developed further through life experience. Usually, children build their talents through engagement in meaningful social interactions and in enjoyable activities that draw upon skills at increasingly demanding levels.

Working memory, as an example of an executive function, has been selected for four reasons. The first reason is that its relationship with mathematical performance has been evidenced in many studies for a wide range of ages [143, 144]. This is especially remarkable in children, where our research is focused [145, 146, 147]. The second reason is that working memory can be used as a predictive element of mathematical skills [148, 149]. This predictive value is more significant than the rest of the executive functions [150]. However, it must be taken into account that, according to [151, 152] executive function of inhibitory control in mathematics problems is greater than that of the executive function of working memory during the first years of schooling. According to [153] the capacity of prediction extends to the first years of primary education. The third is that the predictive value of working memory is influenced by the period of childhood growth, where visio-spatial memory seems very strong [154, 155].

It would be necessary to explain that there is currently no agreement on how to define executive functions, but most authors who published in this field agree that they refer to processes of top-down control. As this is involved in the regulation of the action, these processes are key in early childhood education. For some researchers, the executive functions are constituted by: inhibition, planning, flexibility, working memory, and fluency, while others suggest three functions: a temporarily retrospective function (working memory), a temporally prospective function dedicated to anticipation and preparation of responses, and a mechanism of control of the interferences that suppress the incompatible conducts with the established goal. Despite this, the model of the greater agreement is perhaps the one proposed by Miyake and others

[156]. For them, there are three basic aspects of executive functioning: inhibition of dominant responses, updating, and supervision of representations in working memory and change between tasks or mental sets.

Researchers such as [157, 158] suggest that the predictive capacity of mathematical performance in primary education will be more powerful if verbal work memory is measured because, in childhood, this last skill carries more weight. The fourth reason is that the relationship between the executive job memory function and mathematical performance does not seem to depend on the type of memory to be evaluated, but the importance of each type of memory is not equal for each basic mathematical skill (BMS) [159].

There are several potential benefits for the learning-based approaches which can be identified through the relationship between the EF of working memory and the BMS of children in early childhood education. Bull and Scerif [143] investigated the existence of a relationship between EF and BMS in children in preschool and primary education. The results show that the BMS is significantly related to all assessment tasks. These authors propose that the difficulties of the children in mathematics are due to the poor results in the EF of working memory and the EF of inhibitory control. Espy and others [160] carried out an investigation to determine if the EF were related to the BMS of the children of infantile education. For this, they examined 96 children through EF tasks to evaluate working memory, cognitive flexibility, and inhibitory control. Working memory and inhibitory control predicted early arithmetic competence. In addition, they deduced that the EF of working memory, cognitive flexibility, and specific inhibitory control are related to emerging BMS at the childhood stage.

On the other hand, Geary and others [161] evaluated the relationship between the performance of children in mathematical tests and their performance in completing tasks of working memory and processing speed. They found that children with a normal performance in mathematics were faster and more accurate when responding to tasks that presented demands for identification of numerical sets, recovery, and retention of numerical information, linear estimation, and counting capacity. Likewise, their capacity of recognizing numerical sets was related to their performance in visuospatial working memory tasks. Children with difficulties processed this information more slowly, requiring greater effort in determining the size of the sets.

Bull et al. [160] conducted a longitudinal study in which they aimed to predict whether there is a relationship between EF in the early childhood education stage and a better performance in primary education in reading and mathematics. To do this, they first evaluated children in preschool with regard to EF, in reading and mathematics. Then, they evaluated the boys and girls at the entrance to primary education, at the end of the first year of primary education, and at the end the third year of primary education. The results showed that a better performance in EF gives the children a better performance in reading and mathematics in the entrance to primary education and the first years of this stage. They found that EFs predicted better overall performance and that visio-spatial working memory was a specific predictor of mathematical ability.

Toll et al. [162] carried out longitudinal research to identify whether EF, working memory, cognitive flexibility and inhibitory control can act as predictors of mathematics performance. Results of their investigation show that the working memory EF predicts the performance in mathematics, even better than the preparatory skills of mathematics.

4.1.1. Working memory

The term working memory was proposed by Miller, Galanter, and Pribram (1960)) in their classic book Plans and the Structure of Behavior [163]. Baddeley and Hitch [164] proposed an operating memory model based on three components and, above all, transcended the vision of simple storage capacity. The classic model of Baddeley and Hitch [165] comprises a central executive (a limited controller of attention capacity) aided by two subordinate subsystems: one referred to acoustic and verbal information (phonological chain or phonological loop), and another similar referred to visual and spatial information visuospatial system [166].

However, this classic model has recently been revised by Baddeley with the addition of a fourth component (episodic buffer) to the initial model, which allows the episodic memory systems to be functionally linked to short and long term. Thus, with Baddeley the functioning of the working memory is required, whose basic structures are made up of four components, the phonological loop, the central executive, the visuospatial agenda and the episodic buffer.

The visuospatial agenda would be related to the maintenance and manipulation of spatial and visual information, temporarily storing non-verbal information; the phonological loop would be in charge of auditory and verbal information, providing a means for the brief retention of verbal contents, through its two subcomponents: a passive phonological store (represents information under a phonological code that is lost over time) and an active review process (reviews the representations retained in the phonological store in order to prevent them from being lost); the central executive, considered as an attentional control system and coordinator of the other two subsystems and the episodic buffer, system where phonological and visual information is stored and combined, and also integrates the information coming from the long-term memory, so that a unique multimodal and temporal representation is created [167].

Working memory is necessary to maintain objectives in problem-solving, in the rapid processing of information, in the comprehension of language and the storage of information about a pronounced or read the text while the rest is being coded. Therefore these deficiencies can be considered as a result of insufficient maturity in the development of the executive system or regulator of information processing, to select and direct the use of specific processes, such as memorization and comprehension strategies [168].

Working memory can be a component of great influence on academic performance, although it is not the only one that determines it. Current neuropsychology, with its detailed and rigorous analysis of cognitive processes and their relationship to brain organization and functioning, states that it is not a question of analyzing memory in general but rather of looking at what type of memory is the most basic in the learning process. In this sense, working memory, according to Etchepareborda and Abad [168] is conceived as a temporary storage mechanism, which allows retaining some information data in the mind at the same time, comparing them, contrasting them or, instead, relating them to each other, taking responsibility for short-term storage, while manipulating the information necessary for highly complex cognitive processes, plays an important and basic role in learning processes, which is why it becomes a necessary cognitive domain that the student must possess to achieve optimal academic performance [169].

4.2. Executive functions and development of mathematical skills.

As pointed out by Cardoso and Cerecedo [170], mathematical competencies are linked to being capable of doing. The areas covered by a mathematically competent person are:

1. A conceptual understanding of notions, properties and mathematical relationships.
2. Development of procedural skills.
3. Strategic thinking: Being able to formulate, represent and solve problems.
4. Communication skills and mathematical argumentation.
5. A positive attitude towards mathematical situations and towards their own mathematical abilities [171].

For Nunes and Bryant [172] only somebody who identifies logical rules is able to understand and adequately perform even the most elementary mathematical tasks. Among the diverse notions and mathematical skills that children must acquire throughout preschool and the first years of primary school, those related to the ability to serialize (simple seriation, multiple and transitive inference), classify (simple, multiple classification and class inclusion) and understand the concept of numbers (cardinal principle) stand out. The latter is at the base of the appearance of measurement operations.

Numerous studies have researched the relationship between EF during preschool and the academic performance in mathematics [143, 160, 173]. We will mention only three of them for the sake of the present research study. For example, Bull, Espy and Wiebe [160] discovered that performance in short-term memory tasks and Executive Functions (inhibitory control, cognitive flexibility and planning) was associated with a better initial performance of children in mathematical skills and reading.

Likewise, this academic performance superiority remained throughout the years of primary education. On the other hand, the performance of children in visuospatial memory tasks during the preschool stage would be a good predictor of their mathematical capacity during primary education. Particularly, the visuospatial memory and the working memory were predictors of the mathematical performance of children for all the periods in which they were evaluated. The remainder of the EF (inhibitory control, flexibility, planning) acted as indicators of learning capacity in general. That is, they were not associated with the performance of a specific domain.

Geary et al. [174] carried out a study where they evaluated the relationship between the performance of children in mathematical tests and their performance in working memory (WM) and processing speed tasks (PS). In this study, they found that children with normal performance in mathematics were faster and more accurate when responding to tasks concerning the identification of numerical sets, recovery and retention of numerical information, linear estimation and counting capacity. Likewise, the recognition capacity of numerical sets was related to their performance in visuospatial working memory tasks. Children with difficulties processed this information more slowly, requiring a greater effort in determining the size of the sets.

From another angle, Blair and Razza [175] conducted a longitudinal study where they studied the relationship between some EF (attention control, inhibitory control) and the performance of children in mathematical and language tasks. The children were evaluated twice.

The first time with children between 3 years nine months and five years eight months). The second evaluation was carried out with children between 5 years seven months and six years 11 months). Specifically, the capacities of effortful control, understanding of false beliefs, inhibitory control, attention switching, and intelligence were evaluated. The results of the first measurement did not predict the performance of the children in phonological and letter recognition tasks. Such results would indicate that the influence of the Executive Functions on the academic performance depends as much on the academic competence involved, as in the evolutionary period considered.

It is, therefore, considered as important that the child manipulates mathematical objects, develops his creativity, reflects on his own thought process in order to improve it, becomes self-confident, has fun with his own mental activity, transfers learning to problems of science and their daily life, and finally, it is important to prepare the child for the new, upcoming technological challenges [176].

In the present research study, we developed the executive functions in order to observe their effects on working memory and basic mathematical skills. To this effect, the aforementioned skills or processes concerning them will not be worked on, although they will serve as a basis for the activities that do develop working memory.

TEDI-MATH [177] is a complete battery in which the tests built with reference to a coherent model of cognitive functioning and aimed at evaluating specifically the different cognitive processes that need to be developed and mastered to be able to handle with ease in the field of mathematics. It has 25 different tests grouped in the main areas of comprehension and knowledge that must be gradually mastered: Counting, Numbering, Understanding the Numerical System, Doing operations, etc.

In this way, TEDI-MATH becomes an extremely valuable diagnostic tool. It is not just a test for evaluating school performance, but a structured and complete battery that enables us to understand the root causes of the phenomena observed and, consequently, to design intervention programmes adapted to the needs of each child.

It consists of 25 different tests grouped into 6 major areas of numerical knowledge (Counting, Numbering, Understanding the Numerical System, Operations, Size Estimates). (see Table.4.1).

Table 4.1: Subtests and examples of test-items of the TEDI-MATH

Subtest	**Content and example of item**
1.Knowledge of the number-word sequence	- Counting as far as possible - Counting forward to an upper bound (e.g. “up to 9”) - Counting forward from a lower bound (e.g. “from 7”) - Counting forward from a lower bound to an upper bound (e.g. “from 4 up to 8”) - Count backward - Count by step (by 2 and by 10)
2.Counting sets of items	- Counting linear pattern of items - Counting random pattern of items - Counting a heterogeneous set of items - Understanding of the cardinal
3. Knowledge of the numerical system	3.1. Arab numerical system - Judge if a written symbol is a number - Which of two written numbers is the larger
	3.2.Oral numerical system - Judge if a word is a number - Judge if a number word is syntactically correct - Which of two numbers is the larger
	3.3. Base-ten system - Representation of numbers with sticks - Representation of numbers with coins - Recognition of hundreds, tens and units in written numbers
	3.4. Transcoding - Write in Arab code a dictated number
Continued on next page	

Table 4.1 – continued from previous page

Subtest	**Content and example of item**
	- Read a number written in Arab code
4. Logical operations on numbers	4.1. Seriation of numbers Sort the cards form the one with fewer trees to the one with the most trees
	4.2. Classification of numbers Make groups with the cards that go together
	4.3.Conservation of numbers e.g.: Do you have more counters than me? Do I have more counters than you? Or do we have the same number of counters? Why?
	4.4. Inclusion of numbers e.g.: You put 6 counters in the envelope. Are there enough counters inside the envelope if you want to take out 8 of them? Why?
	4.5. Additive decomposition of numbers e.g.: A shepherd had 6 sheep. He put 4 sheep in the first prairie, and 2 in the other one. In what other way could he put his sheep in the two prairies?
5. Arithmetical operations	5.1. Presented on pictures e.g.: There are 2 red balloons and 3 blue balloons. How many balloons are there in all?
	5.2. Presented in arithmetical format - Addition (e.g.: "6+3"; "5+..=9", "..+3=6")

Continued on next page

Table 4.1 – continued from previous page

Subtest	**Content and example of item**
	- Subtraction (e.g.: “9-5”, “9-. . . =1”, “. . . -2=3”) - Multiplication (e.g.: “2x4” “10x2”)
	5.3. Presented in verbal format e.g. “Denis had 2 marbles. He won two others. How many marbles had Denis in all?”
	5.4. Understanding arithmetical operation properties (conditional knowledge) e.g.: addition commutativity: “You know that 29+66=95. Would this information help you to compute 66+29? Why?”
6. Estimation of the size	6.1. Comparison of dot sets (subitising)
	6.2. Estimation of size Comparison of distance between numbers. E.g.: target number is 5. What number is closed to this (3 or 9)?

Chapter 5

New Paradigms Of HCI For Application Development In Early Childhood Education.

5.1. Introduction

In a traditional classroom, students have limited access to interact with their teachers or with the education material due to the limited allocated time for them. Furthermore, students often wait few days until they receive feedback on their homework exercises from teachers. In contrast, research indicates that significant learning outcomes happen with direct interaction whereby the response and feedback can be obtained directly [178].

Learning through using portable computers encouraged the interaction and speeded up feedback, which in return encourage students to pay extended periods on their learning tasks. Building the student's ability to analyze performance and provided additional timely and targeted feedback when compared to the traditional scholar typical interaction in ancient school rooms [178].

Using software on portable computers has been viewed as a possible tool for serving students to increase their level of motivation, to gain a deeper understanding of ideas and develop higher drawback determination skills [179]. The utilization of computers in school rooms is required particularly with cross discipline educational topics such as Technology, Psychology, Education field.

Electronic games, more than any other interactive technology, became a major part of children's modern culture. However, they're rarely inspired by the academic gain in such culture, an exciting feature of electronic games is how powerful these games to inspire children. A common win when using the electronic games are the active participation, intrinsic and prompt feedback, setting a difficult yet reasonable goals, and a mixture of uncertainty and open-mindedness, contribute to motivation. Motivation plays a central role in any learning activity [180]. Thus, building on the high level of motivation of using electronic games and employee that motivation to serve the education and academia is a very logical step instead of merely for pure entertainment. Analysis indicates that well-designed PC games will meet some of the psychological desires of youngsters and inspire them to need to find out [181].

Many students realize learning mathematics troublesome and they tend to not struggle when they learn the cognitive skills in very traditional and theoretical classroom. Sedighian [182] states that the theoretical teaching practice whereby a teacher encourages students to pay time and interact in mathematical class would achieve half of when a teacher encourages students to learn arithmetic through helping them cognitively to construct mathematical data. Recent researchers studies showed how laptop games are often extremely effective in increasing children's learning and pleasure of arithmetic [183].

5.2. Research Methodology

The analysis and technological development was carried out through a rapid prototyping strategy. This strategy allowed us to validate technological options before implementing the results into an educational application. A pre-test/post-test quasi-experimental design included one control group was used; a group received the same treatment as the experimental one, but without additional technological resources, so it acted as a control group in terms of the effect of technology.

Variables

During the creation stage of the educational application, the following variables were taken into account: Independent variable: Participation or non-participation in the intervention program regarding EF and basic mathematical skills. Dependent variable: Basic mathematical skills, executive functions (working memory)

Participants

In order to implement the program, 2 ICT corners were set up in the C.I.P. Ponte dos Brozos for the experimental group (n=30). The control group was made up of 30 children. All groups (N=60) are in the 3rd grade of preschool, between the ages of 5 and 6 years old. All the participants of the experimental group participated in the educational application designed for this research study with the aforementioned technology. In this application, activities for the development of working memory and basic mathematical skills were carried out. The participants of the control group executed similar activities without the assistance of technology.

Procedure

The study was conducted at the CIP Ponte dos Brozos, which showed interest in this research study due to them being at the forefront of the incorporation of ICT into the classroom. Informed consent was requested through the teachers to the parents or legal guardians of the children in 3rd grade of preschool.

Two ICT corners were created in the school according to the material and the intervention program previously described. 6 chairs and basic furniture were placed in each one of the corners for their use during the scheduled tasks. Other children performed a similar activity in the classroom. Before and after the intervention program the evaluation tests of the dependent variables was carried out.

Although all tasks were designed to suite classroom environment, we have opted for an interactive procedure that integrates technology into the daily functioning of the classroom. All the children participated in the activities, although their responses were collected individually for a thorough follow-up and complete evaluation of the program. All the tasks were carried out on the basis of permanent objects found in the workspace (corner): Chairs, children, tables, books. All of them were identified to the system. This includes participant's name, written form, and a photographic representation of their appearance. Children belonging to the experimental group, divided into groups of 6, have had two weekly sessions of 1 hour in the ICT corner. The duration of the treatment was 4 months (16 weeks), therefore, each participant had a total of 32 sessions in the ICT corner. For the control group sessions were held in their regular classroom without any technological aid.

As the system has been developed to be used for very young children 5-6 years old, the type of interaction has to be very simple. We used only a short set of gestures; select, drag, drop. These gestures are, in general, standard to every application and the devices should recognize them without problems. The purpose of the activity was to engage the participants in drag and drop actions with the Kinect. The drag and drop actions were implemented as follows: the user could select the desired object by moving the Kinect pointer which is a hand on screen over it and closing their palm. Then they could move it to the correct place by moving their hand while keeping the palm closed and drop it by opening their palm. The user could use either hand. However, due to the certain phenotypical characteristics of children such as height, length of the arms, the size of the hand and fine motor skills, the size of the gesture recognizer had to be re-tuned. The process we followed to incorporate gesture is the following:

1. The children play in front of the system, replaying several times the same gesture and recording a series of examples, for these records Microsoft Kinect Studio V2 is used. At least two sequences are needed for each gesture; one for training the system and the other one as a test to check the effectiveness of the recognition results. This step is developed in a test application. Figure.5.1.

2. The characterization of the recorded is performed by a human expert, indicating to the system in which moments the gesture is being performed (when a gesture begins and when it ends) through a timeline tagging using Visual Gesture Building which allows the system to be trained and encoding the gesture in a file.

3. The system is trained using the Adaboost algorithm [184] which allows a sensor to characterize any generated gesture. The effectiveness of the detection of each specific gesture is checked using the data obtained as a test recording file.

4. This information can be imported into Unity3D through the software development kit (SDK) and used for real-time recognition.

Data collection instruments

In order to measure the effects of the program, the initial reading competence and TEDI-MATH test was used before and after its completion. Test for the Diagnosis of Basic Mathematical Skills and three tasks that evaluate executive functions (go/no go, Corsi and Wisconsin). Each Interactive ICT Corner was consisted of a student tracking area. Monitoring was done through a Kinect located in the corners of the work area. This Kinect is infrared signal emitters/receivers that allow the detection of movements. These movements were then recog-

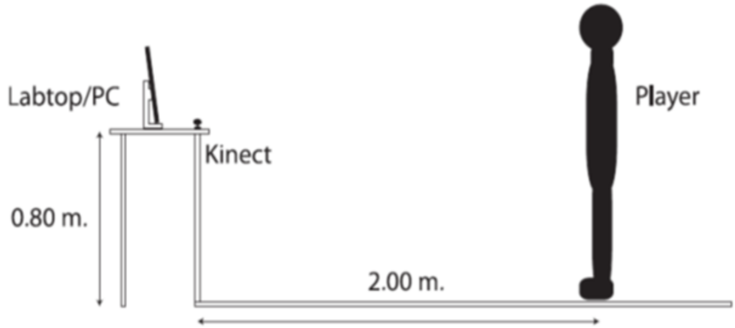

Figure 5.1: Configuration of the Game-Based System Environment Distance between Kinect Xbox and standing point.

nized by the Kinect device. Results (Augmented Reality), were displayed either on a monitor (60 inches approx.), or on an electronic board or similar (already available in the center).

5.2.1. Design Issues to Consider

An important aspect of teaching a subject is the selection of an appropriate supporting materials and tasks [182]. In our case, the game activity is intended to provide a motivating environment for children to engage in Executive Function and basic mathematical skills learning. It is important to design a game activity which matches children interests, while at the same time motivates them to explore the underlying mathematical concepts embedded in the game. Several issues were considered in the design of the game activity:

1. The activity should be designed as a computer game with an interface suitable for children aged 4 to 7.

2. The game activity must support the learning of the educational content and stimulate reflection about the mathematical concepts. It should be designed to prevent children from only paying attention to the entertainment elements in the game, while ignoring the underlying mathematical concepts.

3. The game activity must carefully balance the level of challenge and frustration. “A game can be made so frustrating that the player will soon become disillusioned and

simply abandon it" [185]. "If a game is to provide a continuing challenge to the player, it must also provide a continuing motivation to play.

4. The game activity should have a goal or a set of intermediate goals to achieve. Activities with explicit goals work well for most students [186]. These goals create a sense of mission in children, and it is important that accomplishing the goals can provide them with a sense of success.

5. The intermediate goals should progressively become more challenging: in order to succeed, students should need to continuously increase and refine their understanding of the embedded mathematical domain.

6. The game activity should provide adaptive feedback and rewards. Feedback helps players understand their progress and evaluate their choices and decisions. Progressively reducing visual or auditory feedback in a task can require students to gradually take on greater cognitive responsibility. Rewards such as scoring and sound effects can be effective in increasing students' motivation.

7. Instructional modules should be designed to support more structured and directed styles of learning. These components help children refine and increase their mathematical knowledge from more formal explanations.

5.3. Architecture of the system

5.3.1. Hardware

The hardware used is composed by a PC connected to a Kinect (as somatotype devices) and a big/TV screen where the applications are shown. The learners stand up in front of the screen where they can interact with the applications. The operational details of the interactive game are shown in Figure.5.2, in which (a) the hardware employed is Kinect; (b) a computer is used to drive the program; (c) a human skeleton diagram demonstrates the participant's current body posture; (d) the gesture operation tool allows the participant to interact with the game.

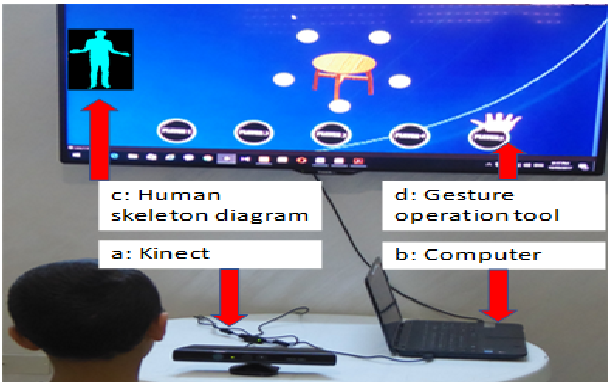

Figure 5.2: Interactive gesture game.

5.3.2. Software

The protocol of GIGL procedure is composed of eight applications; each one presents a similar software architecture, Figure.5.3. The core of the software is a Unity3D application. Unity3D is one of the most popular graphics engines. It is cross-platform (PC, consoles or mobile devices), and used mainly for video game development. For this project, we highlighted two of its characteristics; ease of creating an interactive 3D application, and the ability to support interactive communication with the Kinect. The system was designed for each activity and was integrated into the graphics engine by a script programmed in language C#.

In a relational database, data tables need to be designed to denote realistic relationship of objects. Step one is to design and create relational data tables, for each game. Database management system should support basic “insert”, “delete”, “update” and “query” operations. Thus, step two is to implement these database operations. Finally, the database infrastructure was built and step three is to enter data. The MySQL database was linked to PHP MyAdmin, which is a free, open-source tool written in PHP that can administer MySQL through a web browser. With PHP MyAdmin the user can perform various tasks such as creating, editing or canceling databases as well as executing SQL statements and managing users and permissions.

A website system was created using PHP and HTML. Through this system, the teacher can create a profile for each child contain his name, weight, height, and the picture to use it in the GIGL. The results and data obtained from the above setup were stored in a MySQL database, which was linked to the Unity 3D game platform through an external interface.

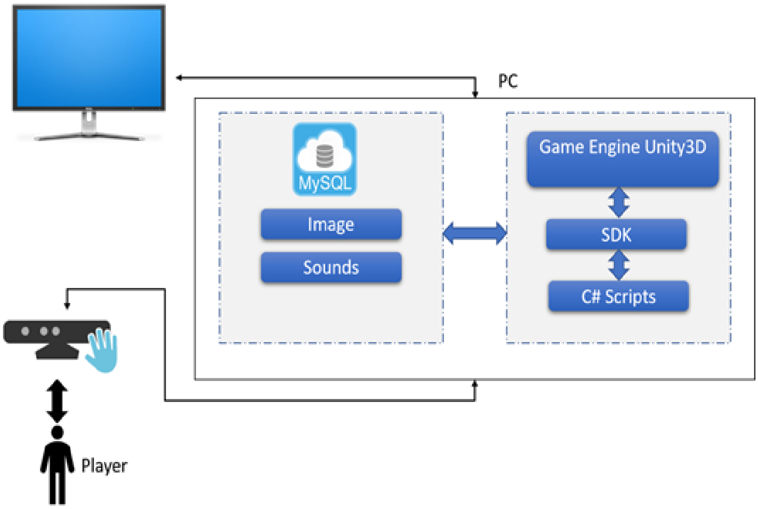

Figure 5.3: System architecture.

5.4. Experiences

In all games, first participants have to listen to the explanation to know what they have to do in the game. In games they have to use their hand as they write in the air, or as drag an object. Their hands are their keyboard and mouse. What they do with them what they see on this screen. On the screen the games that they have to realize will appear.

The "Virtual intervention program to improve the working memory processes in Early Childhood Education" starts with Figure.5.4, which is the access screen, each teacher have a unique ID and password to enter to the system. And then moves on to Figure.5.5, which welcomes the teachers by displaying his/her picture with welcome word.

Next, we turn to Figure.5.6 where we find the main menu of the "Virtual intervention program to improve working memory processes in Early Childhood Education". the main menu options: (1) play the game, (2) Report for the result and (3) exit. and from the "New Game" tab we access the games.

We have developed four games for mathematical learning: “Caught fish”, “Count by jumping”, “Order the numbers ascending and descending” and “The representation of the number on the counter.” The initial prototype contains a single level. When the game begins, the main

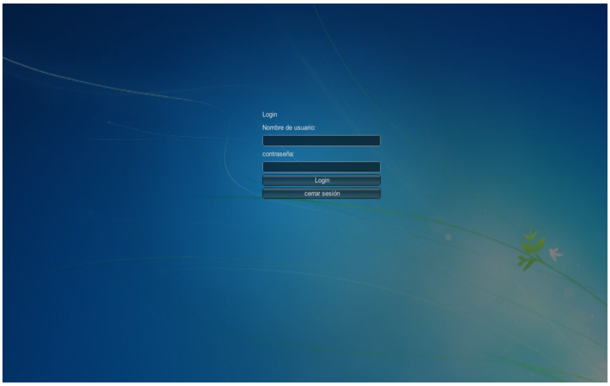

Figure 5.4: Access screen of the "Virtual intervention program to improve working memory processes in Early Childhood Education.

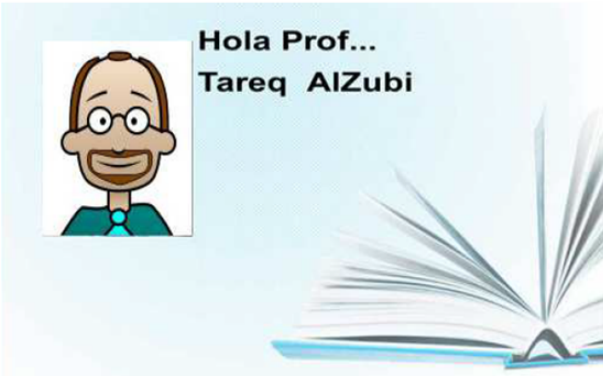

Figure 5.5: Teacher welcome screen of the Virtual intervention.

menu screen shows all types of games for student to decide which game shall they start with, as shown in Figure.5.7.

After the teacher select the game which children will play, anew screen with children picture will appear as show in Figure.5.8. To decide how will start the game by pressing cursor on his/her picture.

The workflow of the application is described to know how it works see Figure.5.9. The classroom teacher was responsible on registering the children profiles in MySQL database in which a unique ID tagged with their photos for easy recognition process. The system

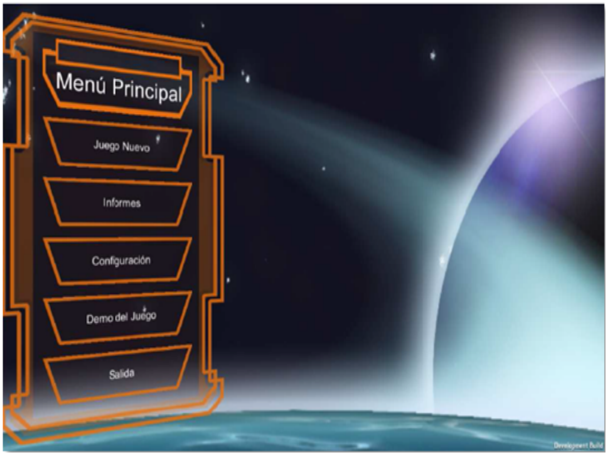

Figure 5.6: Main menu screen of the Virtual intervention program.

Figure 5.7: Main Menu of Mathematical Games.

was designed to display images in the screen in a friendly-use interface within Unity 3D, the design focused on kids using cartoon icons. The application automatically saves the results of each trial of these games; the results will then be stored within each child's profile, in function of how the child responded to the experiment. Also, a message appears telling the children that they completed the game and consequently results (final score) will be saved.

As mentioned earlier in Chapter.3 section3.2. Teachers must determine how these games should be developed in order to obtain the required result. Garris [15] proposed the input

Figure 5.8: Screen of selection of the player of the Program of virtual intervention.

process outcome model (IPO), which has been adopted as a tacit paradigm for most studies on learning games. The IPO model delimits three elements: (1) the input, which illustrates the design of the instructional process; (2) the process, which introduces the cycle of the game and allows for the user's feedback on their experiences; and (3) the outcome, through which thorough analysis of training objectives and outcomes is made. The model was used with all the games that were designed, and this model will be presented with each game description in more detail.

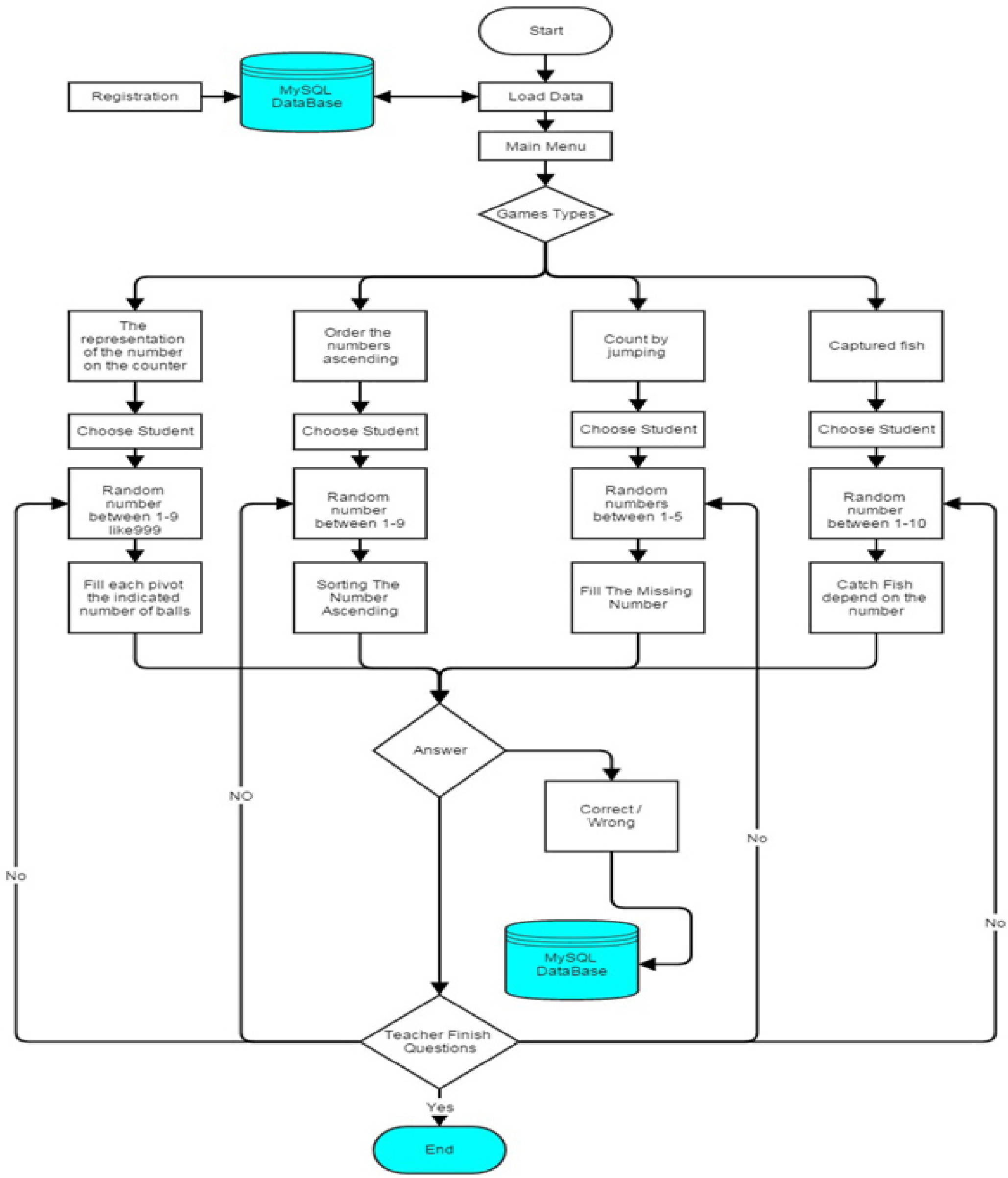

Figure 5.9: System Workflow for Math educational games.

5.4.1. Order numbers ascendingly or descending

In the screen four numbers are displayed to the participating children, they have to catch, drag and drop the number and locate it at the stair in order from the lower to higher. The task will be carried out individually at the classroom, working in the first place the concept of number, the series and the establishment of correspondences. As shown in Figure5.10.

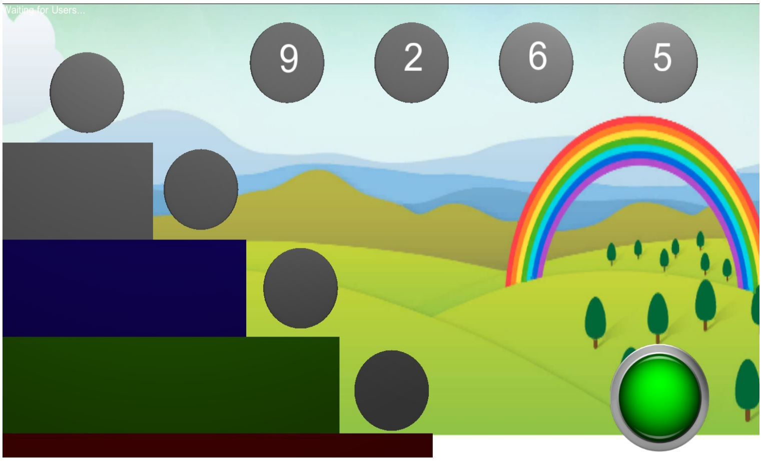

Figure 5.10: Order numbers ascendingly or descending.

Table 5.1: The design of the IPO (Input) Order numbers.

Instructional content.	Game characteristics
The goal of this game is to understand the concept of arranging the numbers in ascending or descending order. The system shows the student numbers on the screen, and the student has to pick up the number and put it in the correct order on the stairs. The child presses the green button to confirm the answer	Fantasy: The number can be touched. Rules/Goal: The number has to be ordered correctly. Sensor stimulate: Visual audio and body control. Challenge: Order and time limit. Mystery: The order and the numbers are chosen randomized. Control: The participants should use the concept the number and use their body to play.

Table 5.2: The design of the IPO (Process)- Order numbers.

User behavior	System feedback	User judgment
The user has to catch, drag and drop the number. Judge the correct order of the numbers. The users have to use their body, hand, and arms in the interaction.-	When a number is located correctly, its trigger a sound and the score is increased.	The user is interested in catching the numbers and enjoys developing the activity with the new interface.

Table 5.3: The design of the IPO (Outcome)-orders numbers.

Learning outcomes	concept of arranging the numbers in ascending or descending order. Working memory is initiated when the students should work with the application numbers to reach the correct ball to put it in the first place and continue to other numbers.

5.4.2. Fishing

In this activity children individually have to catch as many fishes as the number that appears on the screen. The fishes will move fast and the children should develop their ability to catch it. The task will be done individually, and included the concept of number and also the mathematical concept of the sum. The working memory is worked because the students have to remember the number of fishes they have already caught. As shown in Figure5.11.

Table 5.4: The design of the IPO (Input)- Fishing.

Instructional content.	Game characteristics
The goal of this game is to recognize the concept of the number and the process of calculation by catching some fishes. The system shows the student a number on the screen, and the student has to capture fishes as many as the number indicates. The kid presses a green button to confirm his/her answer.	Fantasy:Fish can be touched. Rules/Goal:the user have to capture fishes as many as the number indicates Sensor stimulate:Visual audio and body control. Challenge:catch correct number of fishes . Mystery:The numbers shown on the screen are chosen randomized. Control:The participants should use the concept of the number and the process of calculation and use their body to play.

Figure 5.11: Fishing.

Table 5.5: The design of the IPO (Process)- Fishing.

User behavior	System feedback	User judgment
The user has to catch, drag and drop the fish. Judge the correct number of fishes. The users have to use their body, hand, and arms in the interaction.	Manual control of the virtual objects. Sounds and correct	The user is interested in catching the fish and enjoys developing the activity with the new interface.

Table 5.6: The design of the IPO (Outcome)- Fishing.

Learning outcomes	Concept of the number and the process of calculation. Working memory, the students must remember the number of fish that child has to catches.

5.4.3. The representation of the number on the counter.

In this activity three pivots and a ball in the upper left are showed. The student will have to fit in each pivot the number of balls indicated in the right part of the screen As shown in Figure5.12.The task will be done individually we are working on the concept of number and also the mathematical operation of addition and subtraction. In this mathematical context work memory will be worked. The students have to remember the ball's number of which he

Table 5.7: The design of the IPO (Input)- representation of the number.

Instructional content.	Game characteristics
The goal of this game is to teach the children how to represent a three-digit number on the abacus. The system will show a three-digit number so that the player must drag a ball from the top left corner of the screen and start placing it on the three columns representing each of the: ones, tens and hundreds as required. The child presses the green button to confirm the answer.	Fantasy:The number can be touched. Rules/Goal:represent the number in the pivots. Sensor stimulate:Visual audio and body control. Challenge:Represent the number correctly. Mystery:The numbers are chosen randomized to represent it. Control:The participants should use the concept the number and use their body to play.

has already located in this sense working memory is worked.

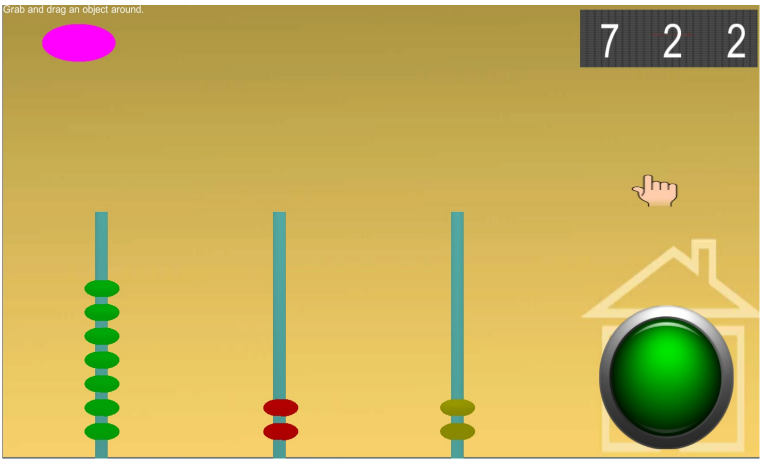

Figure 5.12: The representation of the number on the counter.

Table 5.8: The design of the IPO (Process)- representation of the number.

User behavior	System feedback	User judgment
The user has to catch, drag and drop the ball on the stick. Judge the correct number of the ball on the stick. The users have to use their body, hand, and arms in the interaction-	When student represents the number on a pivot, he/she will press the green button to submit the answer, its trigger a sound and show a correct sign on screen and increase the score.	The user is interested in catching the numbers and enjoys developing the activity with the new interface.

Table 5.9: The design of the IPO (Outcome)- representation of the number.

Learning outcomes	The concept of represents the number of 3 digits on the abacus. Working memory will work because the students have to remember the ball's number to get into each stick and balls that have already entered.

5.4.4. Counting by jumping

The children watch on the screen a row with a set numbers and a blank space and three possible solutions; one number have to be chosen to fill in that blank space. The task will be done individually; working first of all on the concept of number, series and operations of addition and subtraction. The work memory will be worked because the student body has to remember the number and their meaning. As shown in Figure.5.13.

Table 5.10: The design of the IPO (Input)- Counting by jumping.

Instructional content.	Game characteristics
The goal of this game is to fill the space with the missing number within the string of numbers, the line of numbers consists of five numbers, the player must put the correct number with one of the three numbers located below the line of preparation.	Fantasy:The number can be touched. Rules/Goal:fill the missing number in the line. Sensor stimulate:Visual audio and body control. Challenge:fill the correct number and time limit. Mystery: The line number and the ball numbers are chosen randomized. Control:The participants should use the concept the order number and use their body to play.

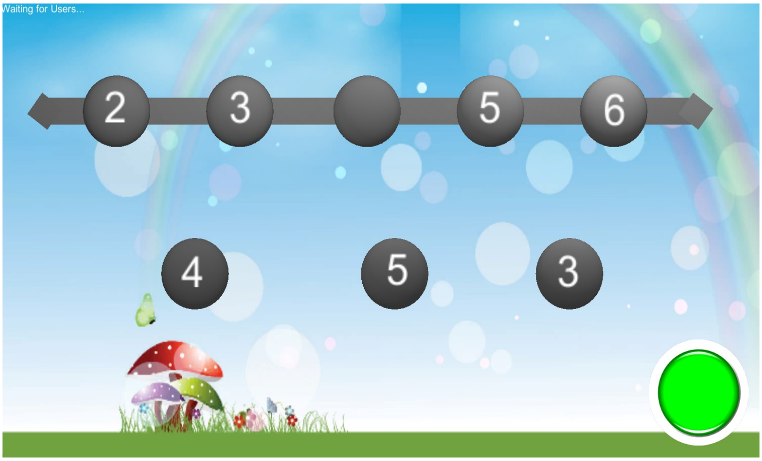

Figure 5.13: Counting by jumping .

Table 5.11: The design of the IPO (Process)- Counting by jumping.

User behavior	System feedback	User judgment
The user has to catch, drag and drop the correct number. Judge the correct number to fill the gap. The users have to use their body, hand, and arms in the interaction.	When student put the ball number in line he/she will press the green button to submit the answer, its trigger a sound and show a correct sign on screen and increase the score.	The participants are interested in playing the game activity with the new interface

Table 5.12: The design of the IPO (Outcome)- Counting by jumping.

Learning outcomes	The concept of sequential completion of five numbers. In this context, working memory and inhibitory control will work. Working memory is initiated when the students should work with the application numbers to reach the correct ball.

5.4.5. Scuba diving.

The task is located in under the see. Two circles one green and another red will be displayed randomly. The child has to catch green or red fish and drop in the circle of its color. As shown in Figure.5.14.To carry out this activity we will give you the following slogan: "Now we are going to do an activity in which we have to fish for fish. As you can see on the screen above there is a circle that sometimes will be green and sometimes it will be red, depending on the color of the circle you will have to catch green fish or red fish and let the fish escape from the rest of the colors ". The task will be carried out individually and in both sessions the 30 children of the technological experimental group will carry out this activity.

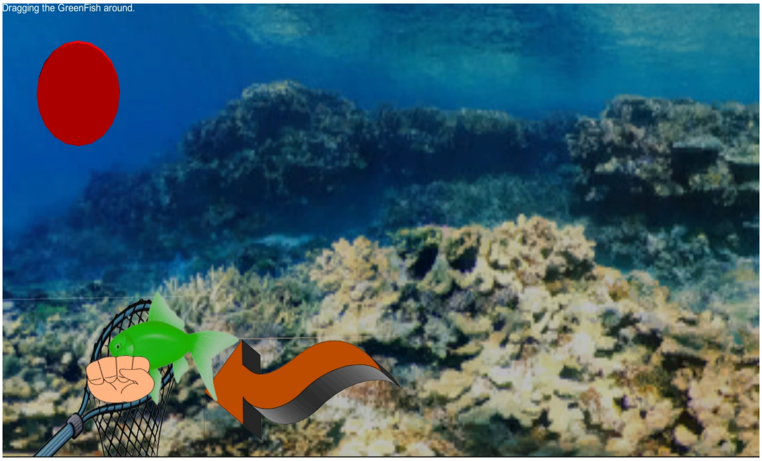

Figure 5.14: Scuba diving.

Table 5.13: The design of the IPO (Input)- Scuba diving.

Instructional content.	Game characteristics
This game contains three parts, in each part system will show 10 fishes in total. A random number of Red, Green and Blue one by one will appear on the screen. The system will generate a random number for each color so that all color will appear on the screen. Part One: (Red Circle) Kids will catch Red fish, and he/s can catch another color. There is a counter for red fish and counter for other fish. To catch the animal's kids can move their hand and grip the animals then drop it in net. Part Two: (Green Circle) Kids will catch Red, Blue animal except for the green and he/s can catch another color. There is a counter for red, bluefish and counter for green fish. To catch the animal's kids can move their hand and grip the animals. Part Three:(Red Green Circle) Children when the circle is red have to catch redfish and when the circle is green have to catch all the fish except green fish. In this part each time a circle will appear on the left corner of the screen, depend on the color of screen kids will play.	Fantasy:Fish can be touched. Rules/Goal:catching the fish depend on the color of the circle. Sensor stimulate:Visual audio and body control. Challenge:Catch the correct color of fish and time limit. Mystery:The color of fish shown on the screen are chosen randomized. Control:The participants should use the concept of the catching and use their body to play.

Table 5.14: The design of the IPO (Process)- Scuba diving.

User behavior	System feedback	User judgment
The user has to catch, drag and drop the fish. Judge the correct color of fishes. The users have to use their body, hand, and arms in the interaction.	When a student catches the fish and drop it in a tent, its trigger a sound and the score is increasing.	The user is interested in catching the fish and enjoys developing the activity with the new interface.

Table 5.15: The design of the IPO (Outcome)- Scuba diving.

Learning outcomes	The concept of color fish depends on the color of the circle. Students have to change the work pattern during the development of the task. With this task, we are working the executive functions.

5.4.6. Chair game.

In the sixth task the students are shown an activity in which they are presented, first, different characters sitting around a table and given a few seconds to memorize the sequence, then they will have to place the characters in the right place As shown in Figure5.15.For the realization of this activity we will give the following slogan: "Now we are going to do an activity in which we have to remember where the characters of the images are sitting. First we are going to have to look at how the characters are sitting, for which we will have a brief time, so you have to be very attentive, and after that time we will have to sit down as we saw on the first screen".

The task will be carried out individually and in both sessions the 30 children of the technological experimental group will carry out this activity. With this task we are working the executive function of working memory. The working memory will work because the students have to be operating with the location of the characters of the application to get to place each one in the right.

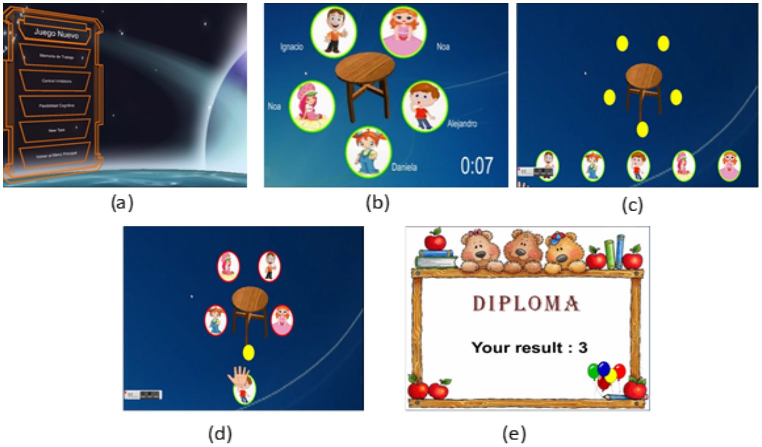

Figure 5.15: Graphic User Interface of the Game-Based System. (a) Main menu of this system, (b) Pictures of the students that the teacher has selected, (c) the system chooses random students to start participating, (d) Test mode by the user, (e) score of user testing.

Table 5.16: The design of the IPO (Input)-chair game.

Instructional content.	Game characteristics
In this task, 5 students will sit around a table and given a 15 second to memorize the sequence, then they will have to place characters in the right place. The student needs to remember where the characters of the images are sitting. After that they will move around the table for a 15 second. after that time we will have to sit down as we saw on the first screen. The task will be carried out individually, and in both sessions, the 30 children of the technological experimental group will carry out this activity.	Fantasy:Simulate a hand on the screen, drag the pictures to the correct place. Rules/Goal:Judge the correct correspondence between the picture and the hand gesture; place the pictures of the children on the right chairs. Sensor stimulate: Visual, audio, and hand movement. Challenge:Correct scoring. Mystery: A random sequence of students participates in the game. Control:The participants need to think, decide, and use their hand to play the game.

Table 5.17: The design of the IPO (Process)-chair game.

User behavior	System feedback	User judgment
The user has to catch, drag and drop the picture of the student in the correct place. Use their own judgment based on what has been displayed. The users have to use their body, hand, and arms in the interaction.	Each time a participant makes a right decision to Arrange the pictures in their correct location its trigger a sound and increase the score.	The user is interested in drag and drop the pictures of the student on the chairs and enjoy developing the activity with the new interface.

Table 5.18: The design of the IPO (Outcome)-chair game.

Learning outcomes	The students have to be operating with the location of the characters of the application to get to place each one in the right place. With this task, we are working executive function of working memory. The working memory will work because the students have to be operating with the correct location of the characters of the application to get to place each one in the right place.

5.4.7. Inside – Outside class

In the seventh task the student is shown an activity in which he is presented. first a screen with ten objects. Among the objects are inside the classroom and outside the classroom Figure.5.16. Next, we go to a second screen in which a male avatar appears for the children Figure.5.17 and a female avatar for the girls Figure.5.18. on this screen the children will have to decide if the object is from outside or from inside the classroom. The first time they do the task, the students will have to raise their right hand if the object is from inside the classroom and do nothing if the object is from outside the classroom. The second time they do the activity, the pattern changes and instead of raising the right hand for classroom objects they have to raise this same hand for the objects outside the classroom and do nothing for the objects inside the classroom. Finally, when a student has decided whether the ten elements presented are from inside or outside the classroom, a third screen appears see Figure.5.19 in which the children will have to indicate the number of objects inside and outside the classroom. To do this they must add or subtract in the counter that appears.

To carry out this activity, the following slogan in the first part of the activity: "Now we are going to do an activity in which a child must first memorize the objects that appear on the first screen. Next, a second screen will appear in which children have to raise their right hand for the objects inside the classroom. Finally, they have to indicate the number of objects inside and outside the classroom in the counter ". In the second part of the activity the slogan will be the same, but instead of indicating that they raise their right hand for the objects from inside the classroom they will raise it for the objects outside the classroom. The task will be carried out individually and, in both sessions, the 30 children of the technological experimental group will carry out this activity. With this task we are working mathematical addition and subtraction operations. In this mathematical context work memory and cognitive flexibility will be worked. The working memory will work because the students in the first screen have to memorize the elements inside and outside the classroom. In addition, in the last screen of the activity they have to indicate the number of objects inside and outside the classroom, so they should remember them.

To finish with the description of the program, we must emphasize that in addition to the aspects we have mentioned in the description of the sessions, we will also work on different aspects: at a mathematical level, space and time, fine motor skills, perceived self-efficacy for technologies and, finally, the motivation. The organization of space is achieved by the child through displacements of his own body and objects. Body is the first element through which you explore space. Afterwards, he discovers the space that surrounds him, his representations, forms, figures and properties. The notions that we will work during the program are: up-down, front-back, side-to-side, right-left, above-below, in front of-behind, besides, near-far ... We will also work on time. Temporary concepts are more difficult to assimilate than spatial concepts because they are more abstract and conventional. However, they will become familiar during the program with some basic notions such as: fast-slow long-little time, duration, succession ... In addition, to work spatial and temporal notions is also intended to improve fine motor skills of students, perceived self-efficacy in relation with the use of technologies and motivation in the face of the teaching-learning process. We believe that the program will help improve fine motor skills because the technology we are working with requires greater accuracy than the same work in pencil and paper. Likewise, another of the aspects that we intend to improve with the program is the self-efficacy perceived by the students in the use and management of new communication and information technologies, since after handling said technology they should be perceived as more effective in the same, improvement that can be transferred to the use of other technological devices. Regarding motivation, we consider that there should also be an improvement in motivation for the teaching-learning process, being greater than in the traditional way of working with pencil and paper. This last aspect is very interesting, because one of the fundamental premises for making meaningful learning is that the student has the intention, that wanting to learn that is the primary and primary objective that should start all educational intervention.

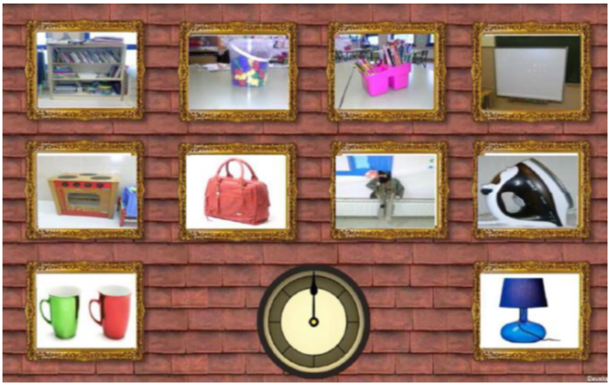

Figure 5.16: objects are inside or outside the classroom.

Figure 5.17: male avatar.

Table 5.19: The design of the IPO (Input) -inside outside.

Instructional content.	Game characteristics
The goal of this game is to remember the picture and decide which picture is inside or outside the class. This game is containing two parts; the first, the part student will decide if the picture is inside the class he /she will raise a right hand up otherwise no raise for hand, the next part he/she will raise a right hand if the picture is outside the class. Each student will do this game alone.	Fantasy:Avatar can move like student movements. Rules/Goal:Raise right hand for inside class picture for the first round, and in second round raise a right hand for outside of class. Sensor stimulate:Visual audio and body control. Challenge:Remember pictures and time limit. Mystery:Pictures showed randomly. Control:The participants should use the concept of remembering pictures and use their hand to play.

Table 5.20: The design of the IPO (Process)-inside outside.

User behavior	System feedback	User judgment
The user has to use right hand to decide the picture is inside the class or not. Use their own judgment based on what has been displayed. The users have to use their body, hand, and arms in the interaction.	Each time a participant makes a right decision its trigger a sound and increase the score.	The user is interested when raising hand and move because the avatar will do the same movement and enjoy developing the activity with the new interface.

Table 5.21: The design of the IPO (Outcome)-inside outside.

Learning outcomes	The concept of remembering the pictures if inside or outside the class and remember the rule of the game when he should raise right hand. The working memory will work because the students in the first screen have to memorize the elements inside and outside the classroom. Also, in the last screen of the activity, they have to indicate the number of objects inside and outside the classroom, so they should remember them.

Figure 5.18: female avatar.

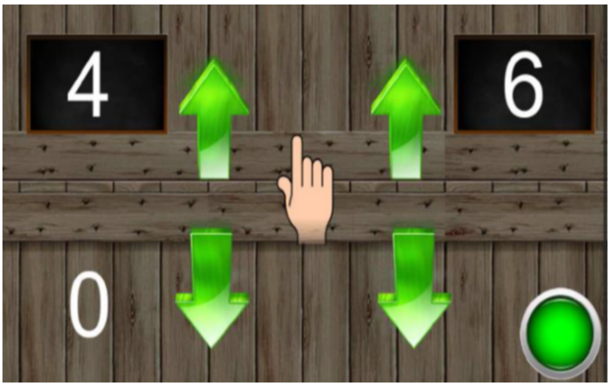

Figure 5.19: The number of objects inside and outside the classroom

Chapter 6

Result and Discussion

This section includes 2 parts, the first is the statistical analysis of data collected when I tested the working memory pre and post-tests then to compare the results with the control group. The second part concerns the use of TEDI-MATH to evaluate the mathematical skills for pre-scholars.

The experimental process design was carried out by a quasi-experimental model with pre-test and post-test with a control group (CG) and an experimental group (EG). In order to avoid problems arising from the sample size (of 60 subject), non-parametric contrast tests were developed, in this case, specifically, descriptive analysis and the Mann-Whitney Test.

To assess working memory, the Corsi Test was used. With this task, we obtained data on three variables that are the total score of the test, the total score of correct answers and the spin memory. To evaluate the basic mathematical skills, the test for the diagnosis of basic mathematical competences, TEDI-MATH, was used. TEDI-MATH is a battery that allows you to identify the difficulties that children of pre-school education have in the numerical field. It is a test of individual application, for approximately thirty minutes, consisting of twenty-five tests grouped into six large areas of numerical knowledge (counting, numbering, Arabic numeral system, oral numerical system, logical operations, operations with image support, operations with arithmetic statement, operations with verbal statement and size estimation) whose internal consistency ranges from 0.84 and 0.99, the test-retest reliability between 0.66 and 0.88 and the construct validity between 0.698 and 0.861. The protocol was developed in five steps:

1. The 60 children were evaluated using Corsi test and TEDI-MATH test.

2. Two homogeneous groups control group and experimental group were developed using a cluster analysis of the previous scores, bellow in order to verify the homogeneity of the groups an analysis of variance ANOVA was performed Median (M) and Stand Deviation (SD) data are given. The researcher assumed that all children do the same in school, even if they are from different classrooms because that is what the teaching coordination bodies of the centers are for. Therefore, as we have two groups in the homogeneous pre-test, one that does nothing and a second that does the same as the previous ones plus the intervention in executive functions if when comparing them in the post-test there is an improvement in the one that received the treatment in the variables under investigation. The researchers also extrapolate to the intervention because there is no other reason to justify that comparative improvement with their peers.

3. The control group continued with standard education methods while the experimental group develops the technology-based activity program. The standard education methods are to continue with the ordinary teaching-learning process that all children of these ages have in the standard educational system, without specific intervention in executive functions. Children of the control group also received the standard education.

4. When the activity program ends the children's, skills were reevaluated.

5. Statistical analysis inter/intra groups were developed.

The statistical analysis of the data has been carried out using the Statistical Package for Social Sciences (SPSS) version 23. As mentioned previously, firstly, two homogeneous groups were developed, under the studied variables (step 1 and 2).

In relation to working memory, the descriptive analysis shows that the groups obtain similar scores between the control group (M = 2.73, SD = 0.78) and the experimental group (M = 2.60, SD = 0.99). Likewise, the Kruskal-Wallis test indicates that there are no differences between groups in working memory (X^2 = 0.48, p = 0.79). From these results, it is clear that the groups are comparable in the working memory variable Table.6.1 .

The same happens with the basic mathematical skills in which the descriptive analyzes shows similar scores between the control group (M = 1046.20, SD = 262.65) and the experimental group (M = 1046.73, SD = 263.90). Likewise, the Kruskal-Wallis test indicates that there are no differences between the groups in basic mathematical skills (X^2 = 0.11, p = 0.95). From these results, it is clear that the groups are comparable in the variable basic mathematical skills Table.6.1.

In relation to the control group and the experimental group, the descriptive analysis shows that the control group obtain scores in the post-test ($M = 2.80$, $SD = 0.89$) lower than the post-test scores of the experimental group ($M = 4.43$, $SD = 0.60$) as presented in Table.6.2 and Figure.6.1. The Mann-Whitney test shows that there are statistically significant differences between the control group and the experimental group ($U = 61.50$, $p = 0.001$) as shown in Table.6.3.

In the working memory variable, there are statistically significant differences between the control group and the experimental group in favor of the research groups that received the educational intervention (experimental group). Therefore, in the working memory variable, there are statistically significant differences depending on whether the children of have received or not educational intervention in working memory, also in mathematical context, in favor of the educational intervention.

In relation to the control group and the experimental group, the descriptive analyzes show that the control group obtained scores in the post-test ($M = 1157.07$, $SD = 259.47$) lower than the post-test scores of the experimental group ($M = 1536.47$, $SD = 131.52$) as shown in Table.6.2 and Figure.6.2. The Mann-Whitney test shows that there are statistically significant differences between the control group and the experimental group ($U = 72$, $p = 0.001$) as shown in Table.6.3. In summary, in the variable basic mathematical skills, there are statistically significant differences between the control group and the experimental group in favor of the research groups that received the educational intervention (experimental group). Therefore, there are statistically significant differences in terms of whether or not the children of early childhood education received the educational intervention, in favor of the educational intervention, but there are no statistically significant differences depending on whether the children received this intervention or not.

The obtained results verify that the intervention in working memory in a mathematical context improves the development of working memory and basic mathematical skills in children in early childhood education. The objective of the present research has been fulfilled, which is to verify if it is possible to improve the performance in working memory and basic mathematical skills through a program prepared for infant education.

In relation to the obtained data in the post-test, the analysis shows that all groups of the present investigation improved with respect to the pre-test evaluation as shown in Table.6.2, in Figure.6.1 and Figure.6.2. In working memory, the control group does not show improvements, while the experimental group does.

Table 6.1: Differences in the pre-test in working memory and Basic Mathematical Skills.

Variable	Group	M	SD	Rank	X^2
Working memory	Control Group	2.73	0.78	17.55	0.48 n.s
	Experimental Group	2.60	0.98	43.45	
Basic Mathematical Skills	Control Group	1046.20	262.65	17.90	0.11 n.s
	Experimental Group	1046.73	262.90	43.10	

*p<.05; **p<.01; n.s.: not significant

In the control group, the post-test scores (M = 2.80, SD = 0.89) are higher than the pre-test scores (M = 2.73, SD = 0.79), and there is no statistically significant differences (Z = -0.20, p = 0.84), in the experimental group the post-test scores (M = 4.43, SD = 0.60) are higher than the pre-test scores (M = 2.60, SD = 0.99), resulting in statistically significant differences (Z = -4.66, p = 0.001). The lack of statistically significant differences in the control group may be due to the cognitive process is not usually explicitly worked in nursery schools, so there is no improvement through the ordinary teaching-learning process. Obtaining statistically significant differences in the groups intervened, the experimental group can be attributed to the educational intervention, obtaining the expected results.

In basic mathematical skills, all the groups improve with respect to the pre-test evaluation. In the control group, the post-test scores in basic mathematical skills (M = 1157.07, SD = 259.47) are higher than the pre-test scores (M = 1046.20, SD = 262.65). statistically significant differences (Z = -3.20, p = 0.001), in the experimental group the post-test scores (M = 1536.47, SD = 131.52) are higher than the pre-test scores (M = 1046.73, SD = 263.90) produce statistically significant differences (Z = -4.78, p = 0.001) as shown in Table.6.2. The presence of statistically significant differences in the control group may be due to the content on which the curriculum is concerned, so it is expected that the participants will gain improvement in the stated variable during the course of the year; while the differences produced in the experimental group can be attributed to the fact that the educational intervention program achieved the results initially proposed.

The researcher also conducted a test to identify the differences between the groups of the present research in the post-test, the Kruskal-Wallis test was used, which indicates that there

Table 6.2: Differences in the pre-test and post-test in working memory and Basic Mathematical Skills

Variable	Group	M	SD	Z	Rank	X^2
Working memory	Control Group	2.80	0.88	- 0.20 n.s	17.77	44.84
	Experimental Group	4.43	0.60	-4.64**	43.23	
Basic Mathematical Skills	Control Group	1157.06	259.46	-3.19**	18.02	41.65
	Experimental Group	1536.46	131.52	-4.78**	42.98	

*p<.05; **p<.01; n.s.: not significant

are statistically significant differences between the control group and the experimental group in the working memory variable (X^2 = 44.84, p = 0.001) and in the basic mathematical skills variable (X^2 = 41.65, p = 0.001).

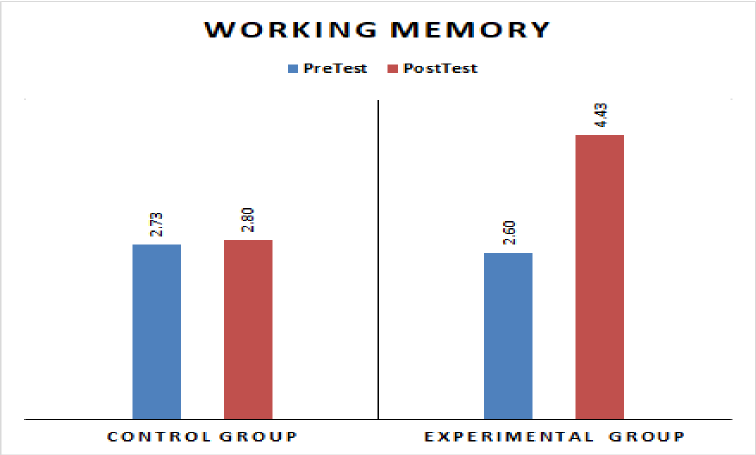

Figure 6.1: Comparison of the mean score in working memory.

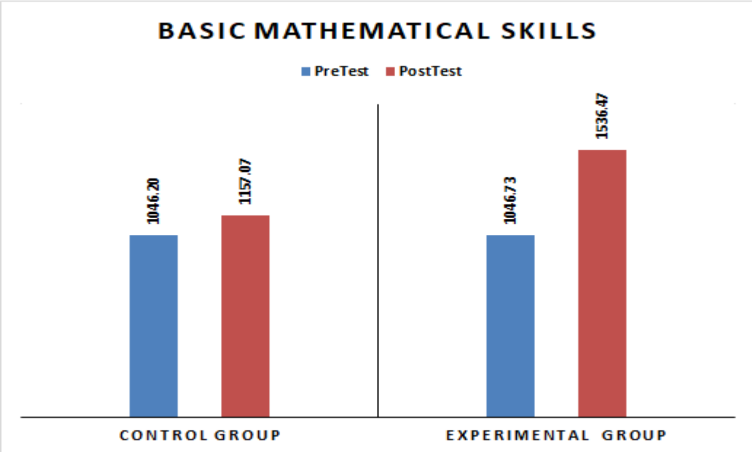

Figure 6.2: Comparison of the mean score in Basic Mathematical Skills.

Table 6.3: U values of the Mann-Whitney pretest/ posttest for control and experimental groups.

<table>
<tr><th rowspan="2">Variable</th><th colspan="2">Pre Test</th><th colspan="2">Post Test</th></tr>
<tr><th>Control Group</th><th>Experimental Group</th><th>Control Group</th><th>Experimental Group</th></tr>
<tr><td>Working Memory</td><td rowspan="2">61.5**</td><td rowspan="2">72**</td><td rowspan="2">68**</td><td rowspan="2">75.5**</td></tr>
<tr><td>Basic Mathematical Skills</td></tr>
</table>

*p<.05; **p<.01; n.s.: not significant

Mathematical skills

For young children, TEDI-MATH was used as an instrument that is validated by a combination of theoretical models and provides an in-depth diagnostic assessment. This multicomponent instrument is based on a combination of neuropsychological (developmental) models of number processing and calculation. It has an age range from 4 to 8 years of age (kindergarten to 3rd grade) and has already been translated into a German, Dutch and French version.

The overall improvement in all of the mathematical skills studied in the experimental group was witnessed, and a smaller increase in the control group. This second case is due to the fact that these skills are included in CVs developed by the control group on a daily basis.

Counting

The comparison of the mean of the counting for the control group and the experimental group shown in Figure.6.3. The post-test of the control group (M = 63.17, SD = 26.128) were higher than their pre-test (M = 47.03, SD = 24.564). The post-test scores of the experimental group (M = 91.10, SD = 8.358) were also higher than their pre-test scores (M = 58.83, SD = 26.856).This indicates that positive impact of the technology on numbering when compared to pretest.

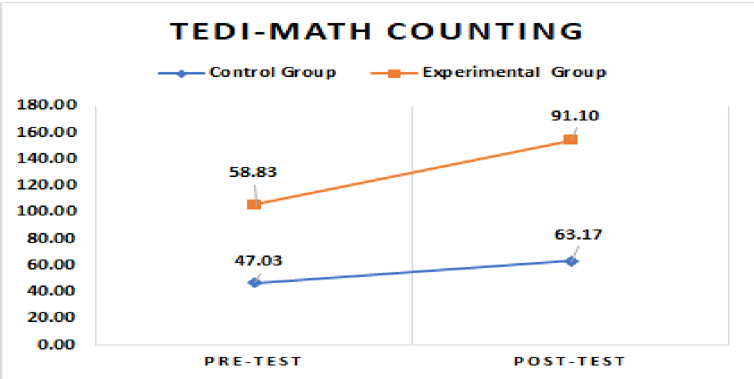

Figure 6.3: Comparison of the mean score in counting.

Numbering

The comparison of the mean of the numbering for the control group and the experimental group shown in Figure.6.4. The post-test of the control group (M = 54.87, SD = 26.388) were higher than their pretest (M = 48.77, SD = 26.388). The post-test scores of the experimental group (M = 93.73, SD = 9.759) were also higher than their pre-test scores (M = 51.13, SD = 25.19).This indicates that positive impact of the technology on numbering when compared to pretest.

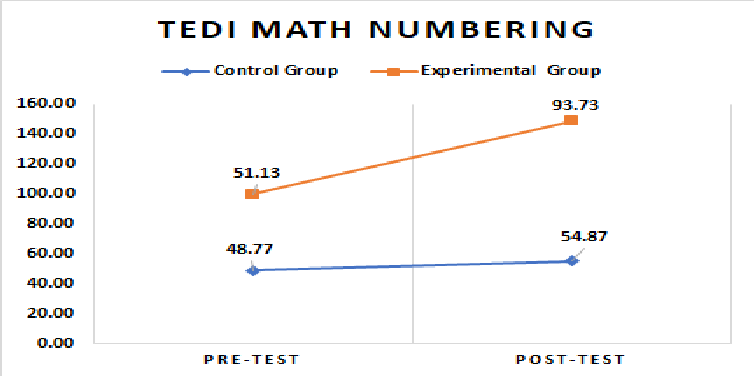

Figure 6.4: Comparison of the mean score in numbering.

Arabic numerical system

The comparison of the mean of the Arabic numerical system for the control group and the experimental group shown in Figure.6.5 . The post-test of the control group (M =83.87, SD = 32.988) were higher than their pre-test (M = 73.07, SD = 36.51). The post-test scores of the experimental group (M = 100, SD = 0) were also higher than their pre-test scores (M = 70.10, SD = 40.66).This indicates that positive impact of the technology on numbering when compared to pretest.

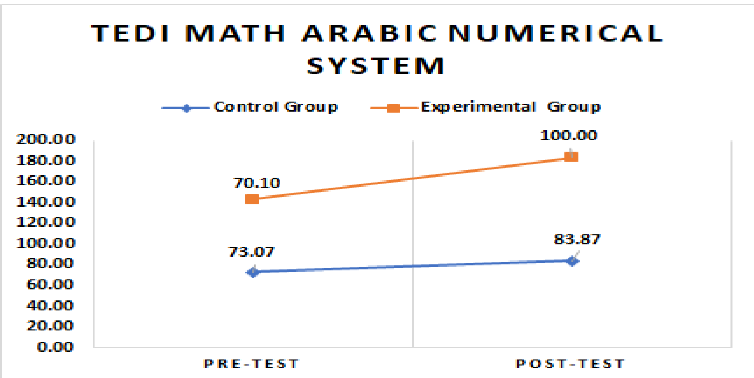

Figure 6.5: Comparison of the mean score in Arabic numerical system.

Oral numerical system

The comparison of the mean of the oral numerical system for the control group and the experimental group shown in Figure.6.6 . The post-test of the control group (M = 47.97, SD = 27.629) were higher than their pre-test (M = 43.70, SD = 28.067). The post-test scores of the experimental group (M = 73.33, SD = 29.128) were also higher than their pre-test scores (M = 49.60, SD = 33.01). This indicates that positive impact of the technology on numbering when compared to pretest.

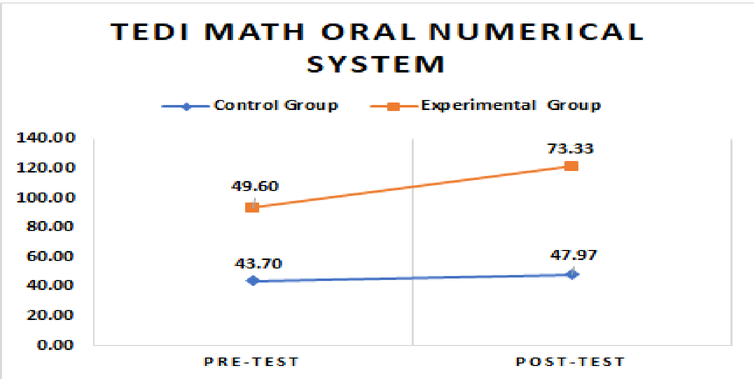

Figure 6.6: Comparison of the mean score in oral numerical system.

logical operations

The comparison of the mean of the logical operations for the control group and the experimental group shown in Figure.6.7. The post-test of the control group (M = 65.47, SD = 26.879) were higher than their pre-test (M = 62.27, SD = 33.511). The post-test scores of the experimental group (M = 86.67, SD = 19.047) were also higher than their pre-test scores (M = 60.90, SD = 29.876).This indicates that positive impact of the technology on numbering when compared to pretest.

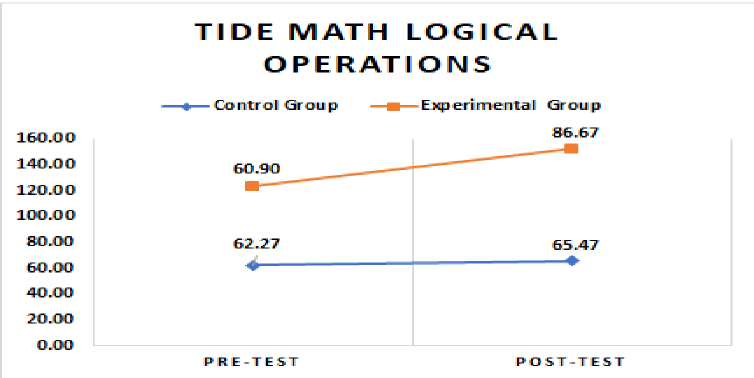

Figure 6.7: Comparison of the mean score in logical operations.

Image supported operations

The comparison of the mean of the image supported operations for the control group and the experimental group shown in Figure.6.8. The post-test of the control group (M = 62, SD = 37.484) were higher than their pre-test (M = 51.93, SD = 35.096). The post-test scores of the experimental group (M = 89.60, SD = 26.968) were also higher than their pre-test scores (M = 36.40, SD = 31.753).This indicates that positive impact of the technology on numbering when compared to pretest.

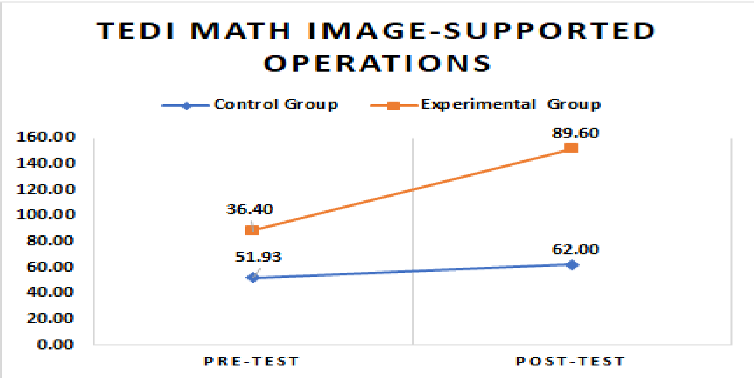

Figure 6.8: Comparison of the mean score in image supported operations.

Operations with arithmetic statement

The comparison of the mean of the operations with arithmetic statement for the control group and the experimental group shown in Figure.6.9. The post-test of the control group (M = 51.50, SD = 33.581) were higher than their pre-test (M = 37.20, SD = 24.842). The post-test scores of the experimental group (M = 77.80, SD = 29.008) were also higher than their pre-test scores (M = 39.37, SD = 32.399).This indicates that positive impact of the technology on numbering when compared to pretest.

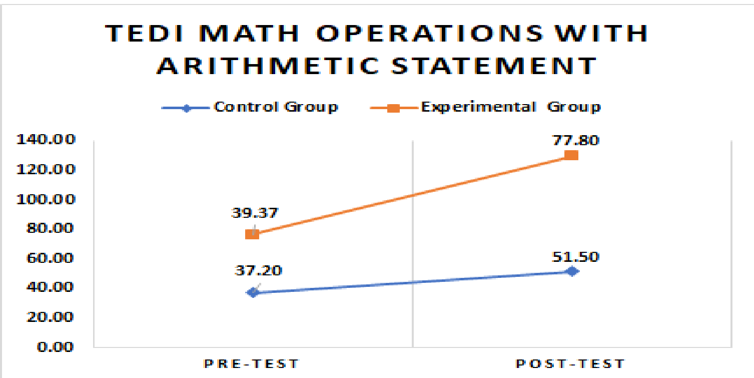

Figure 6.9: Comparison of the mean score in operation with arithmetic statement.

Operations with verbal statement

The comparison of the mean of the operations with verbal statement for the control group and the experimental group shown in Figure.6.10. The post-test of the control group (M = 22.23, SD = 19.33) were lower than their pre-test (M = 29.87, SD = 25.481The post-test scores of the experimental group (M = 41.73, SD = 19.05) were also higher than their pre-test scores (M = 24.23, SD = 25.432).This indicates that positive impact of the technology on numbering when compared to pretest.

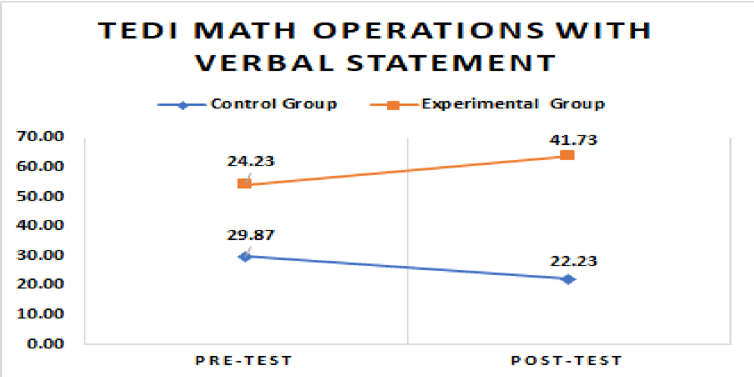

Figure 6.10: Comparison of the mean score in operations with verbal statement.

Chapter 7

Conclusion

This study aimed to develop a favorable virtual interactive learning environment for early childhood. This approach combined the gesture-based learning model and the game-based learning model and aimed at improving the working memory and mathematical skills.

The system described throughout this thesis can be a valuable tool that can help children to interact with new interfaces. It is becoming increasingly important to provide children with a set of interactive games that promote successful learning. It is also undeniable that the use of technology offers an opportunity to enhance learning through the use of a variety of mechanisms, whether for information search or just for providing enjoyable experiences. Therefore, designing systems that meet children's need and that consider both their capabilities and limitations, likes and dislikes, have the potential to create artefacts of sheer importance in the contemporary society.

The research embodied a significant characteristic, in that it can be developed individually, in pairs and small groups. Therefore, it can be considered as innovative, since most educational technology programs are individually developed. Thus, it is decreasing the human and material resources needed. This study also created a physical activity session based on the IPO in order to motivate the learning process, through which the instructor could give suitable feedback based on the individual participant's behavior to encourage their interest in the learning content and to encourage them to accomplish the task through the playfulness of the game.

Data collected from preschoolers and analyzed using the Corsi and TEDI-MATH tests shows a significant increase in the working memory and mathematical abilities of those children who used the technological resources when compared with those used the traditional resources. It has been concluded based on the outcomes of the statistical that using technological resources in teaching preschoolers positively impacted the working memory and mathematical. The results in the experimental one, are along the same line of the results presented by [147, 162, 187, 188, 189, 190]. These differences indicate several things. First of all, that the different applications stimulated the children in a significant way. Second, during the learning process, the system allowed the provision of relevant feedback to the users in order to increase their interest through a desirable set of activities. The set of games with gradual complexity and the characteristic of the IPO model; fantasy, rule/goal, sensory stimulation, challenger, mystery, and control, provided an engaging environment that created a suitable learning environment.

In relation to the visuospatial working memory, I concluded that that all the groups have improved with respect to the pretest evaluation. The improvement of the visuospatial working memory of the technology group and the control group with educational intervention program is in line with the findings of researches such as those of Mammarella et al [189], Wiklund-Hörnqvist et al.[190], or that of Rosas et al. [191]. It was also concluded that there is a great potential to develop the working memory through improving the preschooler's experience by exposing them to the innovative technology which stimulates their enthusiasm to interact with the technology and learn faster Diamond and Lee[192]. Structure and content of the task activities may cause the lack of significance in results obtained from the comparison between preschoolers using technology versus traditional ways of education and not so much the resources used that produce the improvement of the visuospatial working memory.

In relation to the Basic Mathematical Skills I conclude that the improvement of the Basic Mathematical Skills of the experimental group and of the control group with educational intervention programs may be due either to the fact that they are related to the Executive Functions, so that improving these indirectly produces an improvement of the Basic Mathematical Skills, this conclusion is in line with those of Toll et al. [162], Thorell et al. [147], and Wiklund-Hörnqvist et al. [190] or the effect of activities with numbers and mathematical operations reinforces school work.

Finally, this study highlighted the importance of improving the Executive Functions and working memory in preschoolaers Education by the intervention in Executive Functions which allows a better access of preschoolers Education students to Primary Education in general for learning language and mathematics [191]. It is important in the case of working memory

[148, 149] since multiple investigations, such as those cited, show that these are predictive variables of performance in mathematics.

I also recommend for future studies to maximize the number of students participating in the experiment and also to test preschoolers from different backgrounds to delimit any cultural influence on the use of technology on developing and promoting the working memory.

Appendix A

Kinect and Related Knowledge

A.1. Kinect Introduction

Sensing devices emerge due to the advancement of computer based technology and its adaptation in scientific fields. Kinect is a true example of adopting modern technologies in the education process. Kinect is considered the first refined device which captures motions, movement and voices and then convert them into knowledge. Kinect was advanced from the formerly known XBOX360 by Microsoft in 2010 as a 3D camera that captures a real-time image, using RGB camera, infrared transmitters and detecting microphones to capture the finest details on objects. Further on, the technology was assembled and introduced to the market and widespread as a gameplay device. In 2012, Microsoft launched the Kinect project empowered to be compatible with Windows, through special program called "Windows SDK" Kinect is consisted of RGB camera along with CMOS depth camera, infrared transmitters, base motor array and microphones . It rotates on angle ($\pm$27 degrees) therefore, it sights at the maximum possible view (one user) at a time, whereas currently it can track up to two active users. Among the three cameras showed in A.1, the center one is RGB camera, which captures colored pictures at a resolution of 640*480 pixels. The left one is the infrared electrode transmitters and the right one is the dimensional detecting camera which captures dimension at a resolution of 320*240 constituent. The frequency of Kinect image is thirty frames per second and the effective dimension ranges from 0.8 meters to 4 meters.

Figure A.1: Kinect for Windows sensor

A.2. Kinect Principles

The infrared detector and also the dimensional camera are dedicated to get the depth image through using a technology called light-weight cryptography [1]. Compared with previously known technology, TOF (Time of Flight), a special chip (PS1080) is used in light-weight cryptography to regulate the infrared radiation supply. The use of continuous light rather than other pulse light illuminate and casts “stereoscopic codes” to replace the traditional imaging systems of two-dimensional cyclical coding. The three-dimensional coding records also dimensions through using light source. The sensor camera deployed in the three-dimensional coding is a classical CMOS to not only reducing the product cost but also to expand the use of the Kinect in the market.

The light coding technology uses laser technology instead of using geometric logarithm. When the laser beam irradiated on a surface, the spatial scattering phenomenon takes places, thereafter light field that exists near the surface will produce a random laser speckle (Laser Speckles). The laser speckle pattern is highly random. Speckle patterns produced due to laser irradiation are never the same. The uniqueness of speckle patterns enables to label spatial codes within the space and then record the corresponding codes. The system then collects the speckle pattern of an object and matches them with previously recorded codes, therefore determination the position of certain object is doable.

When there is an object in space in a certain position, the position in the image will appear as a peak. The system superimposes these peaks and interpolate to achieve the three-dimensional reconstruction of the shape of object in the space, intercepts will be noted also as a reference to flat which is the how the optical Kinect coding technology performs [2].

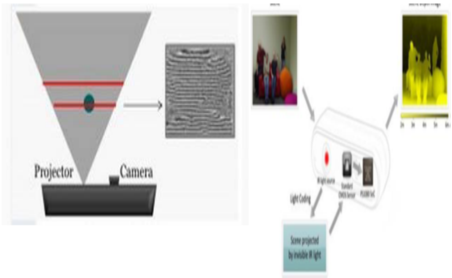

Figure A.2: the left is laser speckles the right is depth camera effects

A.3. Prospects of Kinect Research and Applications

Following the launch of "natural user interface" by Microsoft in 2008 [1], attempts started to develop the concept of the widely spread traditional keyboard and mouse to become a touching, gestural, visual or voice based technology. As Kinect advances, these interactive features entered not only the gaming, but also into the educational and scientific fields. The followings are cases providing an insight into the diverse application of the Kinect into different disciplines:

1. Controlling the presentations: Presentation is the communication channel at conferences, education, business planning most of the industries. The use of Kinect is potential to replace the traditional presentations style of holding a mouse or controller to flip between slides, by using skeletal tracking function of Kinect which can help to identify the user's posture at any time.

Figure A.3: Using Kinect in educational presentations

2. Control Medical Surgeries: The use of Kinect in surgical operations enabled physicians to maintain high level of hygiene while monitoring a real-time functions of patient's organs without the need to touch screens or pc mouse to move or zoom into organs.

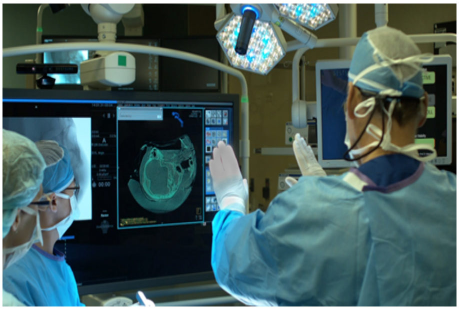

Figure A.4: Using Kinect in medical operations

3. Building 3D model constructions: Using Kinect's dimensional camera to obtain information related to depth, length and width to display a three-dimensional model after scanning the object.

Figure A.5: Using Kinect in building constructions

4. Virtual Dressing: connecting Kinect into a screen enable customers to trying cloths of different sizes or colors instead of relying on physical fitting.

5. Game Applications: "Fruit Ninja" is a true example of the success of Kinect in the game field, the requirement to wave hands in the air to cut the fruit promote the game widely in the market.

Figure A.6: Using Kinect instead of fitting rooms

Several other applications such as dancing without dance brackets "Dance Revolution"; playing tennis without rackets "Power Tennis"; and so on. Several other cases on the prospects of using Kinect in diverse sectors are given in Annex XX. demonstrated the influence of Kinect in changing humans' habits into different way which proves that computers can be adapted to humans' habits and can interact in most life aspects.

Figure A.7: Using Kinect with dance

With the new release of Kinect for Windows, the value of Kinect device is gradually reflected in health care, education and business enterprises. With the release of Kinect SDK v1.7, the functions of push, grab and release motions are added.

Nowadays it is crucial to explore multi uses of Kinect domestically and internationally to attain ease in achieving objectives and also to contribute to the economic growth through creating more job opportunities and introducing innovative services.

A.4. Microsoft Kinect SDK

Microsoft released Kinect SDK to supports audio and the base engine, the SDK is able to track 20 points in an object and can be connected simultaneously with four Kinect devices. Another advantage is that SDK is easy to install and operate, also it is compatible with both the Windows operation system and.Net platform. SDK is also integrated with Visual Studio developing environment. The only limitation with SDK at its first launch was its availability for non-commercial uses only, therefore wasn't able to track some specific parts of the target object. Since February 2012, Kinect for Windows SDK v1.0 was released, and it was featured to

- Support at most four devices connecting with computer simultaneously.
- Near Mode to allow dimension camera to recognize things ranging from 0.4 to 3.5 meters.
- Allow developers to choose the tracking users.
- Improve audio recognition.

Upgrading the SDK was continuous, as an example SDK 1.5 and 1.6 were mainly focused on improving the performance on every respect, whereas Kinect SDK v1.7 released in 2013 was the most important update as it contained Fusion. It used dimension camera to capture and construct a complete 3D models through using constant snapshot in real time. At a later stage it was compatible with Matlab and OpenCV to transform the data formats to suit Matlab and OpenCV requirements. The Kinect Interaction was the most important update in respect of my study. It opened a new door for research using Microsoft in interaction (REFERENCE), the development enabled Kinect to recognize gestures like: Press, Grip and Release . Following this update, the interaction of gestures attracted developers to excel in this field to develop gestures like: click, scroll and drag, consequently increased the interest in Microsoft's Kinect to be used in human-computer interaction. Kinect SDK v1.8 was released in late 2013 included the following key features:

- Exclusion of background. The developed API enabled removing background from behind the active user (green screen) and then replace it with any alternative background. Exclusion of green-screening effect was one of the most requested feature by users. See Figure.A.10.

Figure A.8: real-time 3D reconstruction of Kinect Fusion

Figure A.9: Kinect Interaction: Press, Grip, Release

– Capturing realistic colors with Kinect Fusion, through scanning the color of the scene along with the details on dimensions so that it can capture the color of the object along with its three-dimensional (3D) model. The API then produces a texture map for the mesh created from the scan. This feature provides a reliable 3D model of each scan which includes color and enable the creation of accurate 3D assets for games and CAD.

– Improving and strengthening of tracking using Kinect Fusion. Through using an algorithm to ease scanning of scenes. This particular update helped to lock Kinect Fusion on the scene when camera is repositioned, this lead to yielding a more reliable and consistent scanning features.

– Employing HTML interaction. This interaction enabled developers to work in various programming languages and to integrate Kinect for Windows into their existing

Figure A.10: Example of removing background.

solutions through Kinect-enabled buttons, simple user engagement, and the use of a background removal stream in HTML5.

– Multiple-sensor Kinect Fusion. This feature demonstrate to developers how to use two sensors simultaneously to scan an object from both sides, this feature led to construct a 3D model without replacing sensors and also demonstrated calibration option between two Kinect for Windows sensors, and how to use Kinect Fusion APIs with multi-dimension snapshots.

– Adaptive User Interface (UI). This feature illustrates how to build applications that relies on distance between the user and the screen. The developed algorithm in this feature uses physical dimensions and position of both the screen and the sensor to determine the best ergonomic position on the screen for operating controls as well as ways to adapt UI while users approach the screen or walk back from it. As a result, the UI and visual display adapt to the user's position and height to enable users interacting with large size touch screen displays in comfortable manner.

The most recent released of Kinect for Windows 2.0 SDK from Microsoft (launched in October 2014) contains several new features and documentation capabilities as follows:

– Windows Store Support. The latest version of Kinect for Windows enabled users to develop and publish applications, these applications can then be stored in "Windows Store". Kinect SDK and functioning sensors are available in the API surface, except the speech detection sensor.

– Unity Support With the latest release, the Kinect API set is available for the first time in Unity Pro , through Unity Package. This advancement provided a platform for developers to develop core functions like: visual gesture building and face recognition, these features were available under Unity apps. Based on the flexibility of this feature, this study was mainly centered on linking both Kinect and Unity.

– .NET APIs The Managed API set was a continuation of previous version with extra features to help developers cope with the fast developing environments, and to be able to shop without the need for further investment.

– Native APIs To help users comply with Kinect applications requirements for full power and high speed to be able to write using C++. The Native APIs iterate the native APIs for Kinect. The form and structure of the APIs are identical with the Managed API set, yet it allows developer to utilize a full speed C++. The Native APIs are considered significant shift from the v1.x native APIs, and also way easier to use.

– Audio A high class array microphone and advanced signal processing to create a virtual became doable with Kinect sensor and SDK. The software based microphone has high detection capabilities of not only the audio but also the direction where audio came from, consequently provides high quality input for speech recognition.

– Face APIs Face APIs was an extension to provide a variety of functions to enable face recognition experiences and build multi scenarios. Within the Face APIs, developers are now able to detect faces within the view of the sensor, and then align faces to 5 unique facial identifiers, and track the orientation in real-time. The High Definition Facial Recognition (HD) provides 94 unique "shape units" per face which create meshes very closely identical to the face. These meshes then can be tracked in real-time following the user's facial movements and expressions.

– Kinect for Windows v2 Hand Pointer Gestures Support This feature enabled users to control their applications through using a hand pointer gestures. This improvement included ControlsBasics-XAML, ControlsBasics-WPF and ControlsBasics-DX.. The DirectX is built over theToolkit Input component.

– Kinect Fusion The Kinect Fusion applications were built on Kinect for Windows, so users can develop and deploy Kinect Fusion applications with higher resolution, improved camera tracking and performance compared with V 1.x releases of Kinect Fusion.

- Kinect Studio To provide users with customized and controlled Kinect Studio, a new user-interface came to offer flexibility in the layout of various workspaces and offered different views. Moreover it offered a platform to compare two 2D or 3D views side-by-side or to create a custom layout to meet user's needs. This also enabled to separate the monitoring, recording and playback streams and to expose the additional functions such as stream-level metadata. Features related to timeline such as: in- and out-points to be able to control which segment of the playback is required to play; pause-points that let users to set multiple points to suspend functions like playback and looping or markers, that enable users to attach meta-data to various points in time.

- Visual Gesture Builder (VGB) It is a gesture detector builder that uses machine-learning and body-frame data to 'define' certain gesture. Multiple body-data clips are marked 'tagged' with metadata related to the gesture which then is used to match certain gesture definition from the body-data clips, gesture detection runtime is used to detect gestures. The machine-learning for gesture detection offers a path to rapid prototyping. Using VGB view, users can benchmark gesture definitions without the need to write any code.

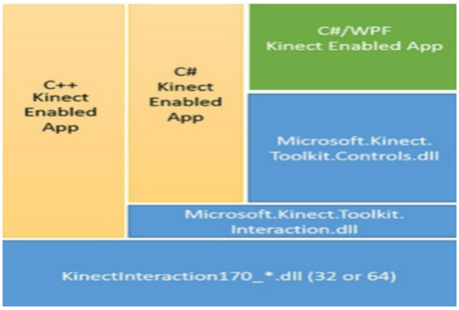

Figure A.11: the framework of Kinect Interaction

The Kinect sensor for both Windows and Windows SDK created an opportunity for developers to excel in building wide range of applications such as:

- Real-time video capturing using color sensors

- Tracking human movement and analyzing the body movements and identify gestures through employing natural user interface
- Quantifying distances and lengths through measuring the distance between objects and between objects and the 3D camera.
- Data Analysis, in particular the 3D data to further develop a 3D model.
- Generating an interactive depth map for objects to be tracked.
- Voice recognition which assist in developing hands-free applications which can be operated by voice.

Therefore, Kinect for Windows SDK has been selected as the backbone in this study to build educational game to test the working memory of school kids.Figure A.12 show the evaluation of the Kinect for Windows SDK

Figure A.12: Evaluation of the Kinect for Windows SDK

A.5. Human Skeleton Tracking

The Kinect sensor communicates the raw depth data which is collected for certain object, each pixel of that object is given in a form of value which indicate the distance between both the sensor and the object. The depth data provides users with unlimited scenarios to deploy into Kinect in order to build an application that interacts with users. The depth data also enables experienced user with a tool to control over applications related to body and object motions.

In order to build these interactive applications with body motion, it is crucial to capture data on bodies standing in front of Kinect, off these bodies, the Kinect will track the skeleton through illustrating the whole body in picture.

Using skeleton tracking, the Kinect sensor tracks human body through focusing on various joint points. Using the Kinect for Windows SDK, users can track up to six participants/target bodies and up to 20 joints for each skeleton/body.

Off the six bodies, only two of them can be thoroughly tracked, which means the sensor can communicate information related to the twenty tracked joint points; whereas, for rest of the bodies, will be tracked only their overall position.

After Kinect sensor sends back the raw depth data, it becomes easy to identify and match pixels bodies. Skeleton tracking is not made to track joints by matching with body/player information; instead it tracks the complete body movement using a real-time human pose recognition. The challenge in recognizing the real-time human pose is due to the diversity in body poses, sizes, dresses, and heights. For poses, a single body can be detected when it moves randomly into various destinations and for size.

To efficiently track such multi-joint body pose, Kinect had rendering pipeline to match incoming data from the sensor with existing sample datasets. The human pose recognition uses a developed color vision algorithm which uses several base character models; these models vary in heights, sizes, clothing, and several other physical factors. The previously identified datasets are collected from the base characters of the body and includes different types of poses, hair styles, and clothing, and in different displayed patterns (rotated). The previously identified datasets are then matched and labeled with individual body parts given the incoming depth data to precisely identify the captured body part. A multi-step data analysis then takes place in the rendering pipeline to track body parts using depth data.

The Kinect sensor identifies pixel range of a certain body from the depth data. Initially, the rendering pipeline process relies on the sensor to identify certain body or object, this process produces just raw depth data which can be similar to any other object captured by the same sensor. Having no in-depth data analysis will result in the sensor being unable to differentiate between objects and bodies. To illustrate how the sensor performs, Figure A.13 displays how a human body looks like using the raw depth data, obviously in this case there has been over estimation to the body.

In recognition of human body, the sensor matches the incoming depth data at single pixel level with the previously built-in dataset. The sensor is able to match pixel with built-in dataset

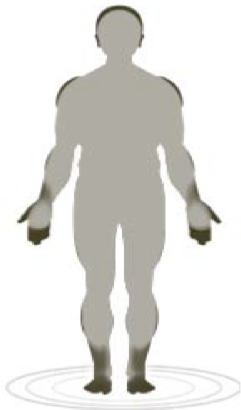

Figure A.13: Illustrate the over estimation of body with sensor using raw depth data.

at a very high speed. The full matching between captured pixels and existing datasets is based on probability that the captured data matches with the existing one.

To better illustrate the labeling process, each nodes in the in the body/object are following different model character data labeled with certain body part. Each single pixel passes through a tree shape data to match with relevant body part. The entire matching process of data then runs several attempts to assure precision, as soon as the sensor matches body segments, then it starts shaping up the body as shown in Figure A.14

Upon identifying the entire body, the sensor starts to position joints using the highest probability of the matched data. Following the movement of joint points, the sensor then track the movement of the entire body. Figure A.15 shows tracked joints of various body segments.

Positioning the joints takes place at a 3-D level, the three coordinates (X, Y, and Z) are taken into account when positioning a joint, where X and Y are defined as the position of the joint and Z represents distance between the joint and the sensor. To maximize the precision in getting the coordinates, the sensor calculates the coordinates at three views: front view, left view, and top view. The three views are illustrated in Figure A.16

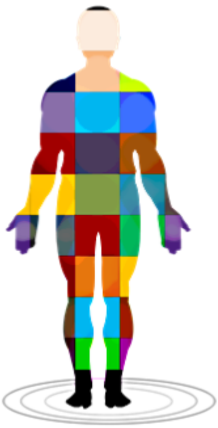

Figure A.14: Creating body segments.

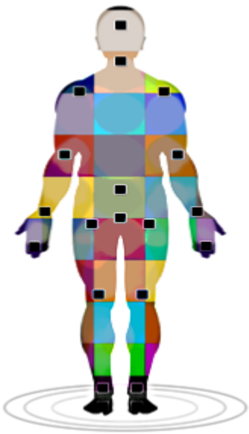

Figure A.15: Tracking entire body after following the joint points.

A.6. Skeleton tracking with the Kinect SDK

The Kinect for Windows SDK provides a set of APIs to facilitate the access to joints as the SDK supports tracking of up to 20 joint points at a certain time. Joints are then identified by their position within the body and given the relevant part name whether it is a head, elbows shoulders, ankles or arm. Skeleton-tracking state is determined and classified as: Tracked,

Figure A.16: Illustration of the 3 view (top, left and front views)

Not Tracked, or Positioned only. Using multiple channels to detect the skeleton, the SDK provides precise recognition service. A default channel can tracks the 20 skeletal joints and their position then classify then classify them as: Tracked, Not Tracked, or Inferred tracking mode. To better illustrate how the default channels perform, Figure A.17 demonstrated an entire human skeleton captured by Kinect sensor and shaped with 20 joints which what the Kinect for Windows SDK tracks:

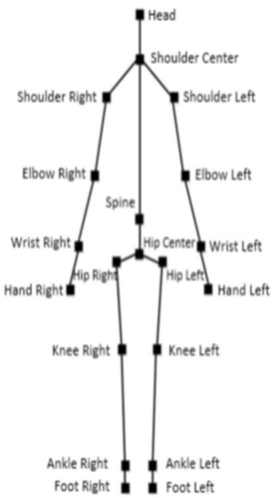

Figure A.17: Tracking and shaping an entire body with 20 joints by the Kinect for Windows SDK.

As introduced previously that the Kinect fully tracks up to two bodies at a certain time and also has the ability to detect a maximum of six bodies within the range; this means that there will be four skeletons are proposed. The fully identified body means that the complete 20 joints are easily tracked, however for the remaining four bodies; only data such as hip center joint will be identified. Kinect for Windows SDK will treat one of the 2-fully tracked bodies as active whereas the second will be considered as passive based on data analysis model. In case of fully tracked body (active), , the Kinect for Windows SDK will receive returned data from the next successive frames, whereas for the passive, only proposed positions will be collected by sensors. Figure A.18 shows the fully tracked body for two different users:

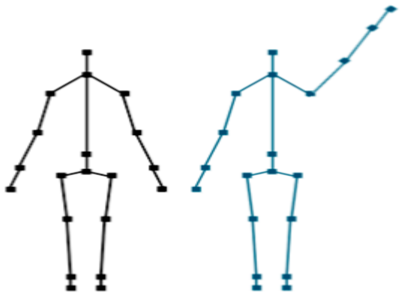

Figure A.18: Illustration of 2 individual bodies and how they have been tracked (actively and passively).

The Kinect for Windows SDK not only tracking standing bodies/objects but also can track seated bodies. The SDK provides a feature to change the tracking mode from standing to seated, choosing this feature will only be able to return data of up to 10 joints only which is half of what can be achieved at the standing position, illustration of what the seated position can return is given in Figure A.19

In summary, this chapter covered topics related to how tracking of human body works at different positions, sizes, colors, and lengths. Our goal from writing this chapter is to layout the methodology for writing up the application which will assist us in detecting the human movement and position in front of Kinect and then illustrating the movements of body joints.

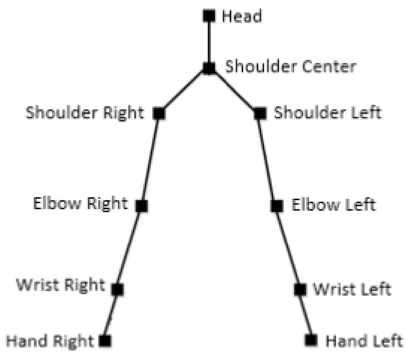

Figure A.19: The number of joints that can return data under seated position.

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