Augmented Reality for Educative and Collaborative Environments

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Título en español

Realidad Aumentada Para Ambientes Educativos y Colaborativos.

Title in English

Augmented Reality for Educative and Collaborative Environments.

Resumen: Esta tesis muestra el proceso de desarrollo y construcción de EducAR (Educative Augmented Reality) un sistema de educación virtual para ambientes sincronos y asincronos que utiliza realidad aumentada como tecnologia central de enseñanza. EducAR se compone de un modelo pedagogico llamado Augmented Learning, un conjunto de estrategias de aprendizage y una aplicacion de enseñanza virtual. Esta aplicación integra un modelo de comunicacion y un modelo de interaccion. El modelo de comunicacion implementa una conexion UDP para crear un ambiente colaborativo de aprendizage, en el que todos los participantes comparten los modelos 3D de realidad aumentada estudiados y pueden realizar preguntas al docente sobre estos, las acciones realizadas por un usuario son replicadas a todos los demas asi como la respuesta a la pregunta. El modelo de interaccion relaciona las actividades de los usuarios con los modelos 3D de realidad aumentada permitiendo realizar rotaciones en el eje X y Y, zoom y seleccion de una parte del modelo en particular, para esto se usan 2 formas de interaccion, mouse y teclado y el Wiimote .

Abstract: This tesis shows the developing and construction process of EducAR (Educative Augmented Reality) an e-learning system for synchronous and asynchronous environments that uses augmented reality as central learning technology. EducAR is composed of a pedagogical model called Augmented Learning, a set of learning strategies and a virtual education application. This application uses a communication and an interaction model. The communication model implements an UDP connection for creating a collaborative learning environment, where all the participants share the 3D augmented reality studied models and can make questions to the teacher about them, the actions made by any user are replicated to all of them, also the answer to the question is replicated to all the participants. The interaction model connects the user activities with the models allowing the rotation in the X and Y axis, zoom, and selection of a specific part of the 3D augmented model, in order to do this two interaction forms are used, mouse and keyboard and the Wiimote .

Palabras clave: Realidad aumentada, E-learning, educación virtual

Keywords: Augmented Reality, E-Learning, Virtual education

Dedication

This thesis is dedicated to my mother for her constant, unconditional love and support. I also dedicate it to the memory of my father, who would have been happy and proud to see me finish this process

Acknowledgments

I would like to thank to my thesis advisor Jonatan Gomez Perdomo for his dedication, direction, and discussion. His efforts and support made this work possible. Also, thanks to my friends in the Alife research group from Universidad Nacional de Colombia. Without their time and cooperation, this work would not have been completed.

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Introduction

The increment of internet connections in the world (near 2,4 billion) has allowed people to reach a large quantity of contents, people can obtain knowledge of any topic in a easy way. This has created a high educative demand, where students and teachers do not share the same physical space. Several applications have been created to accomplish the task of delivering information using electronic media and internet networks but the transmission model that still dominates education has changed little [23].

Virtual education also called e-learning emerges to supply this need, using all the electronic and technological media available, in order to facilitate the action of sharing knowledge between geographically distanced people [10]. E-Learning has been credited with having the potential to "improve the quality of learning, improve access to education and training, reduce the cost of education, and improve the cost-effectiveness of education" [62]. Thanks to this Virtual education is taking more importance for the educative institutions. An example of this is the case of Standford University. in 2011 they make available for everyone its first free online platform for online courses(Coursera). Having more than 60 thousand students enrolled and during its first 13 months in operation, ending March 2013, Coursera registered about 2.8 million learners [61].

According to Clark and Mayer [13], e-learning or electronic learning is any instruction that is delivered on a computer which has the following characteristics:

- Includes content relevant to the learning feature.
- Uses instructional methods such as examples or practical exercises to help learning.
- Uses a variety of media elements to deliver the content and methods.
- Builds new knowledge and skills which are linked to improve organizational performance.

This definition and others that where studied do not take into account the relation between the electronic and the learning components. In order to build a successful e-learning experience the different learning mechanisms must be studied. So for this work the e-learning perspective defined by Dabbagh [19] is used. In this perspective there are three key components that must interact in order to create successful learning applications which are:

- Pedagogical Models: are the cognitive models created from views about the knowledge acquisition process that form the basis of learning theory. Those models are the ways that describe how theory and practice is linked. Some of the cognitive models that will be developed in the next chapters are: cognitivism, constructivism, active learning, distributed learning and augmented learning

- Learning Strategies: are "the plans and techniques that the instructor uses to engage the learner and facilitate learning" as described by Jonassen, Grabinger, and Harris [34]. Learning Strategies put in practice the pedagogical models guiding the creation of the activities that will deliver the content in different ways depending on the needs of the group. Examples of Learning strategies are: problem solving exploration, collaboration and social negotiation, role playing activities, articulation, reflection and others.

- Learning Technologies: are the tools that join the the learning strategies with the pedagogical models. And are the ones in charge of deliver and transmit the contents to the learning subjects. In 2001 Richard Clark [14] established that the medium (computer technologies) does influence learning. However, it is not the computer per se that makes students learn, but the design of student's interaction with real-life models and simulations. The computer is merely the vehicle that provides the processing capability and delivers the instruction to learners.

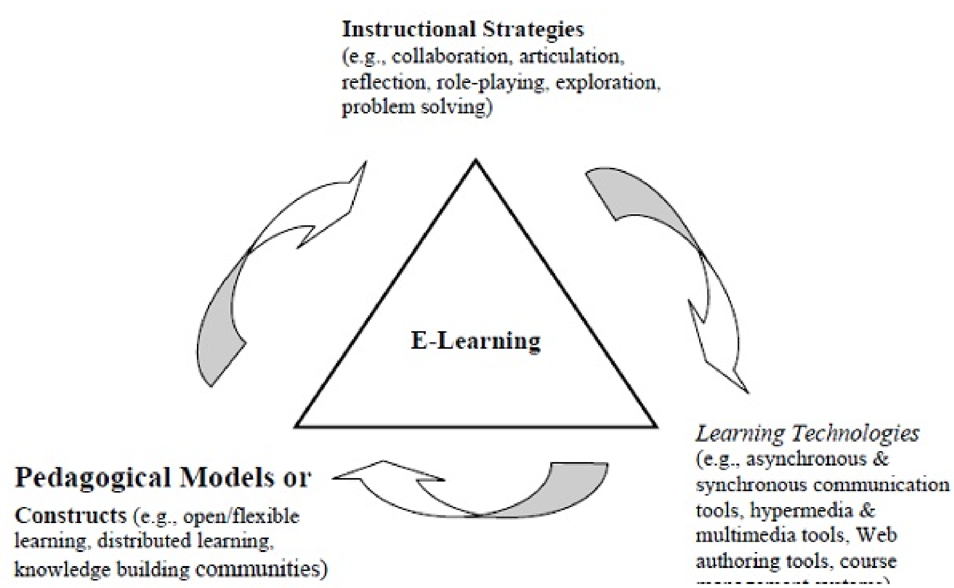

FIGURA 1. e-learing key components [19]

E-learning technologies have come a long way since PLATO (Programmed Logic for Automatic Teaching Operations) the first computed assisted instruction system created in 1962 by Donald Bitzer [6] PlATO Used monochromatic displays as and infrared sensor and interaction technology. Also the educational courseware and electronic notes served as communication form with other users. Up to the recent years when Massive Open Online Course (MOOC) and virtual reality applications took prominence.

This document will be focused on one particular technology called Augmented Reality [16],[36],[55], this technology was defined by Julie Carmigniani as a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer generated information to it [11].

Augmented reality systems were also defined by Azuma[2] as those that have the following three characteristics: i) Combines real and virtual, ii) Interactive in real time, iii) Registered in 3D

In other words augmented reality its capable of combine 3D objects, images and text with the view generated from a computer camera adding virtual generated information to the objects in the real word. As can be seen the use of Augmented Reality facilitates the study of physical and real life phenomena by adding virtual generated information to them. Or by recreating objects that can be difficult to study in normal conditions in form of 3D models which can be as detailed as needed.

The use of augmented reality applied in the virtual education field has been explored by many researchers [59][46][7][1][35] showing great potential and learning characteristics that can help to improve the educational field as it will be studied in further sections.

This document was written following two fundamental assumptions: the first one is that the design of e-learning courses and technologies should be based on a cognitive theory of how people learn. And the second one is that such design of e-learning courses should be based on valid research studies about the interactions that could help the learning process. Following that assumptions in this document a learning system that uses the characteristics of augmented reality to reinforce the qualities of e-learning and smooth its defects is followed. Such model incorporates a set of tested interactions between participants applied in collaborative distributed and educative environments that can work in both synchronous and asynchronous mode.

GOAL

In this thesis an e-learning system that uses collaborative Augmented Reality is developed taking into account and integrating three key factors: first a pedagogical model known as Augmented Learning. Second the instructional and communication strategies that can be used in this context. and third the interaction and collaboration techniques that can be applied when using Augmented Reality.

This e-learning system called EducAR (Educative Augmented Reality) is designed to help teachers and students to interact in a distributed and online way, using Augmented Reality as central and integrating technology. EducAR allows the use of any kind of 3D objects to teach different subjects. In this document the organic chemistry subject is used as an example due to the visual and spatial characteristics that some of the topics required, and the 3D structure that the chemistry models have.

This Thesis shows that the use of Augmented Reality in the virtual education context in a personal or collaborative way enhances the interest of the students and can lead to the appropriation of new concepts. It is also showed that the use of non typical Human-Computer interaction forms also help to improve the learning process and experience

The general objective is to propose and develop an e-learning system that allows communication between 2 or more people through virtual environments using collaborative augmented reality in order to be used for synchronous and asynchronous blended learning

Specifically, this research concentrates on:

1. **To create a learning technology that uses Augmented Reality combining an interaction model and a communication model**

   A very important step in the creation of a successful learning experience when different interaction and visualization technologies are implicated, is to identify the different activities that the user can perform and the adequate way to link this activities with the studied objects, in this case the Augmented reality 3D models. This link is represented by an interaction model that uses the Wiimote as non conventional human computer interaction device, capable of perform all the user activities in an easy and pleasant way. Also the use of conventional devices like mouse and keyboard is also studied, in order to provide an alternative that does not generate additional costs while maintaining the same functionalities .

   The communication model was designed in order to create a virtual collaborative experience where the communication between participants, and the information flow can be like in real life. To do this the communication model must be capable of establish a many to many communication with low latency between messages. A multicast UDP connection was selected due to its characteristics, setup and configuration options.

   The communication and interaction models are joined in EducAR application. creating a virtual environment where students can interact with the models and with other participants in an easy way

2. **To establish a suitable pedagogic model and a set of instructional strategies for Blended Learning using synchronous and asynchronous content delivery**

   A successful and complete learning system must take into account the learning theory, its concepts, strategies, models and perspectives. EducAR implements a pedagogic model known as Augmented Learning which combines cognitive and situational land cognitive earning perspectives in order to deliver knowledge through meaningful activities. Those activities are executed by the instructional strategies which are based on simulations, work by groups and feedback between participants.

3. **To integrate the learning technology, the instructional strategies and the Pedagogic Model into an e-learning System**

   In EducAR the Augmented Learning pedagogic model defines the cognitive view of the system and leads the creation of the instructional strategies which are enacted through the learning technology. This leads to a learning system which not only creates am interactive and interesting way to deliver knowledge but also a whole set of theoretical and practical means for students to appropriate that knowledge

4. **To evaluate and analyze the results obtained:** Two user test were made in order to evaluate the performance of the different components of EducAR. The first user test was done at the end of the first phase of the project, 20 participants used the application and gave valuable feedback about the interaction model and the use of Augmented Reality in a learning experience. in the second phase 20 students took a full class using EducAR synchronous mode: 10 using the Wiimote and 10 using mouse and keyboard as interaction devices also 10 students acted as control group studying the concepts just using a printed version of the class

MAIN CONTRIBUTIONS

The main contribution of this work is to develop an augmented reality system designed for e-learning that can be used for synchronous, asynchronous and self placed learning. The system called EducAR (Educative Augmented Reality). Follows the Theory Design Framework proposed by Dabbagh [19] implementing a pedagogical model, a set of instructional strategies and a learning technology.

The following is a list of this Thesis contributions:

An interaction model that uses Wiimote or keyboard for Augmented reality manipulation

One of the key components for a successful virtual learning experience is the interaction between the users and the technology. As Augmented Reality is not a common learning technology a set of interaction techniques must be studied. In order to increase the appropriation of knowledge participants must have all their attention in the learning materials and not in the way to interact with them. The set of interaction activities contains: three axis rotation, increasing and decreasing the zoom level, selecting a specific part of the model and change the model.

The selected interaction device must have high customization abilities thanks to different contributed libraries, an easy connection interphase with the computer and a low cost. So a non conventional but proven interaction device like the Wiimote is used. The interaction model also takes into account common human computer interaction devices such as mouse and keyboard, these devices can be used to interact with the augmented reality models and can provide the same interaction activities but as is proven not the same acceptation. The interaction model was tested in the two phases of the project development showing very interesting results.

A communication model designed for Synchronous e-learning using UDP multicast

The design of an effective communication model is one of the most important activities for synchronous content delivery. Teachers and students must have a way to interact and share their concepts, views and experiences. The metaphor of a class room is widely used because helps to structure the learning experience and provide a familiar context within which participants and presenters can interact [31]. The created communication model provides a set of functionalities that support that metaphor like hand rising, collaborative content manipulation and sharing the same view of the model.

EducAR: an e-learning system that allows communication between 2 or more people through virtual environments using collaborative augmented reality

EducAR(Educative Augmented Reality) is an application designed for teaching in virtual learning environments using collaborative augmented reality in order to display and interact with 3D models of organic chemistry. EducAR can help the teaching of a wide set of concepts like basic organic chemistry, chemical reactions and stereo isomerism. EducAR allows students to explore phenomena in ways not previously possible while using a style with which students and teachers are familiar. Through technology-enabled learning and interaction face to face with their peers, students can engage in deep and meaningful explorations of complex topics. EducAR enhances the educational experience in synchronous and asynchronous environments promoting the appropriation of new concepts. It is also explored the use of interaction techniques based on the Wiimote, mouse and keyboard improving the interaction between the user and the 3D generated content.

THESIS OUTLINE

The structure of the thesis is as follows:

- **Chapter 1** provides an augmented description of the background about augmented reality: its technologies, components and applications and a description of the the pedagogic model and learning activities that will be studied
- **Chapter 2** Presents the first phase of EducAR development: the architecture of the system, its main software and hardware components, proposed interaction technique and the results of the first user test
- **Chapter 3** Presents the second phase of EducAR development with the changes and improvements based on the discoveries from the previous chapter: the improved architecture, users and roles implementation, the implementation of the learning activities and the results of the second user test

CAPÍTULO 1

BACKGROUND AND JUSTIFICATION

1.1. AUGMENTED REALITY

Augmented reality (AR) is a content delivery and interaction technology that is gaining interest from different audiences, due to its capabilities of mixing virtual content with the real world in different proportions, achieving a very high of detail by using 3D models, images and text while conserving the necessary real life view. Augmented reality allows a level of immersion that no virtual equipment can provide [63].

Augmented reality (AR) can be defined as a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it [11]. Augmented reality systems were also defined by Azuma[2] as those that have the following three characteristics:

1. Combines real and virtual
2. Interactive in real time
3. Registered in 3D

In order to identify Augmented Reality systems and differentiate them from virtual Reality systems Paul Milgram and Fumio Kishino created the Virtuality Continuum (Figure 1.1) an schematic line that describes the relation between real and virtual environments and the systems that are in the middle.

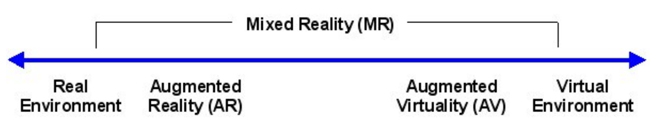

Figura 1.1. Reality virtuality continuum [52]

Augmented Reality systems differ from Virtual Reality ones in the level of immersion that the user experiments. For example, a typical virtual reality system uses especially designed rooms with a complex hardware that includes a set of cameras, video projectors, and other sensory devices. Those configurations immerse the user into a synthetic world without seeing reality. In the other hand augmented reality systems usually work with commercial cameras or hand held devices. Putting new information over the objects in the visual range of the camera or 3D models on some figures that act as markers giving additional information to the users, enriching any kind of content or simulating local interaction with the 3D models.

Due to its characteristics Augmented Reality Systems can be used to enrich video conferences systems, synchronous and asynchronous content delivery platforms and standard classrooms, combining real video with 3D models that can be presented and manipulated by the participants. This lead to the development of new and better ways to exchange and manipulate multimedia content, this can be used by remote collaborative work and e-learning applications, This kind of applications have a great potential and will be studied in more detail in the upcoming sections.

1.1.1. Augmented reality technologies

In order to integrate Augmentations with the real world, augmented reality depends widely on computer vision and pattern recognition algorithms. Depending on the degree of immersion and the specification of the application, Augmented Reality objects can be presented using different hardware devices like monitors, head mounted displays, hand-held devices and other similar devices. And can be manipulated using different interactions techniques and devices like speech recognition, gesture recognition, different types of sensors and common devices like mouse and keyboard.

1.1.2. Computer vision

Computer vision algorithms make possible the calibration, recognition, registration and tracking processes that are essential for augmented reality applications, those algorithms also eliminate the errors and return the coordinates in the scene where the virtual objects are going to be.

Calibration in the context of three-dimensional computer vision is the process of determining the internal camera geometric and optical characteristics (intrinsic parameters) and the 3D position and orientation of the camera frame relative to a certain world coordinate system (extrinsic parameters) [48] the acquisition of this parameters is a key procedure in order to eliminate the error created by the optical acquisition process that can lead to a poor user experience.

One of the most important steps in Augmented reality applications is the process of identify the scene elements and match the virtual augmented models with its respective objects in the real world, this is called image registration and is normally divided in two steps. The first step is the detection of points, figures or regions in the camera images that will be augmented using algorithms such as feature detection, blob detection, tresholding, edge-corner detection, and so on. The second step takes the data obtained in the first step and use it to transform the 2D coordinates in the image to real world 3D coordinates, this can be achieved using epipolar geometry, homagrafy estimation, SLAMP (simultaneous localization and mapping) and other techniques

1.1.2.1. Markers

Markers are the most extended way to facilitate the registration and tracking processes, a marker also called fiducial marker (figure 1.2) is a black and white square with a set of geometrical shapes designed to be easily detected and tracked by the classic algorithms, reducing the computational effort and making possible the real time calculation of the marker coordinates. Black and white markers are not the only ones available, there are also color markers [44], polkadots markers [27] and others.

FIGURA 1.2. Marker example

the relationship between marker coordinates and the camera coordinates is estimated by image analysis (figure 1.3). Kato and Billinghurst in 1999 [36] were the first to introduce the use of fiducial markers in augmented reality applications, determining the way to recognize the marker and track its coordinates in real time.

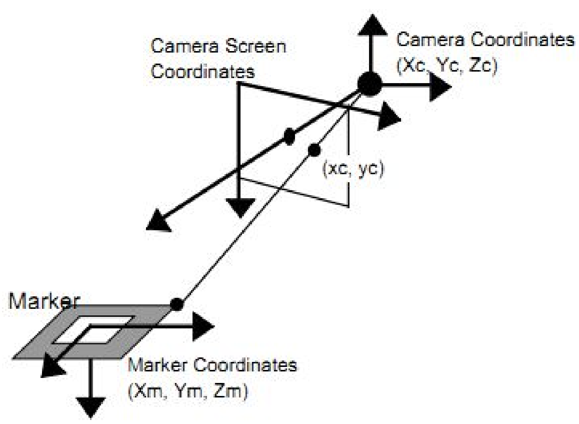

FIGURA 1.3. Relationship between marker coordinates and the camera coordinates

With the popularization of the fiducial markers in augmented reality a lot of frameworks and libraries appeared ARToolkit [36] (and its ports FLARToolkit, NYARToolkit), ARTag [21] and ARToolkitPlus [60]. Those frameworks provide the required libraries for developing Augmented Reality applications in a easy way, and using different programming languages like Java, C++ and action script. Helping to popularize the developing of augmented reality applications.

However Fiducial markers have some limitations: 1) the relation between its size and the distance to the optical acquisition device, 2) depending on the shape of the geometrical internal figure the registration and tracking quality can variate, 3) due to its shape and color the users have a feeling of strangeness causing an uncomfortable interaction with the applications.

1.1.2.2. Marker less

Marker less Augmented Reality systems intend to enrich the user's vision of reality providing additional information or overlapping 3D models without the use of any kind of marker or prior information of the scene and in real time. In order to do this, algorithms need to recognize precise objects or characteristics over an scene by its spatial relations. This process is complicated given the variety of configurations of the scene, the noise, the kind of objects and different characteristics.

With the help of enhanced computing power in the recent years, and the advance in robotic and computer vision systems, markerless augmented reality has become possible.The use of multi threading computing to separate and compute interest point detection and tracking and pose estimation in real-time was used by Taehee Lee et al [45] and Georg Klein [39]. Another approach is to identify planes in the scene by recognising series of points and correlating theirs coordinates [43] [12] best known as PTAM algorithm (Parallel tracking and mapping). A mixed approach where there is an initial user participation to indicate 4 points in the image that form a square in the real scene in order to generate the initial coordinate system was proposed by Park et al [56].

1.1.3. Applications

Over the years researchers and developers have found more and more areas that could benefit from augmentation. The first systems focused on military, industrial and medical applications, however Augmented Reality systems for commercial, entertainment and educational use appeared soon after.

Augmented reality has a wide range of applications, as any kind of information can be enriched, modeled and overlapped onto the user's vision, AR systems can help to solve problems in some areas or even create new services.

1.1.4. Collaborative

Collaborative applications development is one of the most promissory fields for Augmented Reality systems, in the recent years this kind of applications have become more important for enterprises and general public, AR technologies applied for this kind of applications have been studied for several years giving solution to some problems and creating new services, some of the collaborative applications studied during this research were:

In [9] Wolfgang Broll et al present a system for collaborative work focused on architectural design and urban planning where participants interact with a immersive mixed reality environment using head mounted displays. the system overlaps architectural plans and designs in the user's visual field that can be handled and manipulated using a specially designed pointer (fig 1.4). The application allows the creation of a new workflow where participants can manipulate the virtual objects using the basic geometric transformations or adding new objects to the environment. The system showed to be efficient for new users and was easy to use once they get used to it.

Figura 1.4. Users collaborating using the ARTHUR environment

Tek-Jin Nam and Kyung Sakong present in [53] a collaborative 3D workspace created to enhance collaboration in regard to shared objects and shared workspaces, they developed a Sync-turntable which is a rotating synchronized table that provides intuitive physical representation of shared virtual 3D models. It also provides a physical cue of the remote participant manipulation, using virtual Shadows to project body and hand silhouettes of remote participants, which provides natural and continuous awareness of the location, gestures and pointing of collaborators.

Augmented reality has also been used to complement the video conference making possible a better integration of multimedia contents in the video streaming, which leads to a superior experience to the participants. In [4] Istvan Barakonyi et al developed a video conferencing system that uses 3D graphics that are overlapped over the videostream, facilitating communication between the participants. One of the objectives of the system was to be low cost, so fiducial markers, and regular web cameras and the library ARToolKit were used. Additionally, they made a study on the type of markers and distance for optimal recognition, in order to have a more reliable and confident system (figure 1.5).

Figura 1.5. AR Videoconf System.

In [25] Dan Gelb et al present a similar videoconference system that uses Augmented Reality to integrate 3D models in the videostream; but also present a gesture recognition system created to interact with the 3D models and the other participants, indicating regions of interest and pointing or manipulating specific multimedia contents, in order to do this they use a depth camera with infra-red signals and a rule-based system, this make possible that the system can identify the hands and gesture that the user makes.

1.1.5. Education

Education is an important issue in every society, with the popularization of the internet, more people have access to online learning courses, thanks to Augmented Reality characteristics, new and more interactive applications can be developed, allowing the interaction with augmented 3D models that can facilitate the understanding of the concepts presented in class.

acording to Ying Li [46] some of the benefits of AR in education are:

1. Reduce the Deficiency of Education Conditions
2. Avoid the Danger Brought by the Real Experiments or Operations
3. Break the Limitation of Space and Time
4. Virtualize the Figure of a Character or a model

Due to the importance of these applications, several researches have been conducted over this topic, creating very interesting and promising applications. somo of them will now be presented:

In [59] Thomas et al Present an interesting application developed to facilitate the teaching of anatomy to first year medicine students, this application has great advantages as it reduces the need of cadavers for study, this results in a reduction of costs, also the observations and dissections can be repeated the required number of times. One of the most important requirements in this application is the need of realistic virtual models, in order to achieve this a rapid prototyping laser machine is used to scan models of organs in a fast and accurate way. The system uses magnetic markers that let users interact freely with the models without affecting the tracking of the marker. The system additionally overlaps some information on virtual models to highlight specific parts and give more information.(Figure 1.6)

Figura 1.6. Student using the medial AR system

Sang Hwa Lee et al [46] show a system designed to facilitate the learning through augmented reality and manipulation of three-dimensional content. they use a colored type of markers that are used on the fingertips, specially designed to facilitate the interaction as they are invariant to illumination and easy to track, in addition to prevent the occlusion that occurs when using the system, they implement a feature extraction algorithm that tracks the images even if they are partially occluded. This system was used to create an augmented book that helped the students to learn concepts of astronomy in a visual and interactive way as can be seen in the figure(1.7).

FIGURA 1.7. example of a student using the system

Botden et al [7] Presents an interesting augmented reality training application designed for laparoscopic surgery, they design and construct a simulator that contains a series of sensors and cameras which estimate the time, steps taken, and quality of the procedure, telling the user in what direction should be sutured, the pressure necessary and even the angle, the system was evaluated with a group of students showing that with only 7 simulations, the maximum performance was achieved. The system can reduce costs and facilitate access to these practices to a large number of students (Figure 1.8).

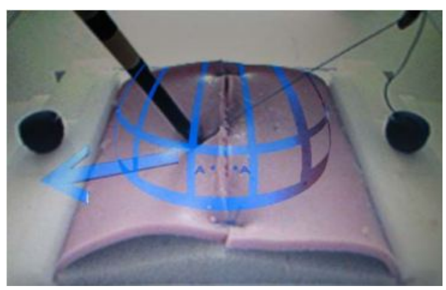

FIGURA 1.8. Example of guided training

In [1] ElSayed et al presents ARSC: Augmented reality student card, an e-learning application designed to be a low cost solution to all educational areas, the systems represents the lessons in 3D format on a card that is delivered to the students with seven markers that were specially chosen using experimental tests, using four of the seven markers the students can manipulate the 3D objects like a virtual keyboard making easier to understand the lessons, also other multimedia content can be displayed such as videos, games and pictures allowing the students to learn new concepts, deal with experiments and demonstrations in a new and innovative way.

Juan Carmen et al [35] developed an augmented reality system that supports the educational process of teaching reading and writing to children in preschool, the system is specially designed for this audience. they use a series of markers that will have images of letters generated with augmented reality, and design some games: spell the word, find the initial and final letter, the system was designed to be as simple as possible so the children only had to move the markers according to the objective of the game (Figure 1.9).

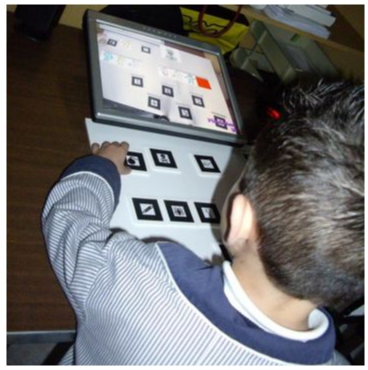

FIGURA 1.9. Child playing the AR game

1.2. E-LEARNING AND PEDAGOGICAL MODELS

E-learning can be defined as the learning of content via all electronic technology, including the Internet, intranets, satellite broadcasts, audio and video tape, video and audio conferencing, Internet conferencing, chat rooms, e-bulletin boards, webcasts, computer-based instruction, and CD-ROM. [58] E-learning is distinguished from distance learning or technology-delivered learning because e-learning includes methodologies where instructors and learners are in the same room or the instruction is computer-based and there is no distance involved [42].

In general, any educational application requires technological, pedagogical and psychological aspects to be carefully investigated before the implementation [38] In this investigation both points of view, the technical and the pedagogical are taken into account. To begin with the pedagogical point of view the learning perspectives that are the roots of e-learning and come from the psicological learning theory should be studied. A review of the main Learning perspectives can be found on tables 1.1 and 1.2 :

1.2.1. Learning perspectives

- **Associative:** The associative perspective is focused on behavior modification via stimulus-response, trial and error learning, learning through association and reinforcement, and observable outcomes, and gives rise to behaviorist theories.

  Merrill propose five principles describing a set of instructional design assumptions that help the understanding and design of elearning courses using the associative perspective. these principles propose a problem-based approach to learning, where students are involved in demonstrations, application and integration of skills, providing a highly focused set of objectives, described as learning competencies [51]:

  - Demonstration principle: learning is promoted when learners observe a demonstration.
  - Application principle: learning is promoted when learners apply the new knowledge.
  - Task-centered principle: learning is promoted when learners engage in a task-centered instructional strategy.

  - Activation principle: learning is promoted when learners activate relevant prior knowledge or experience.
  - Integration principle: learning is promoted when learners integrate their new knowledge into their everyday world.

- **Cognitive**: The cognitive perspective views learning as transformations in internal cognitive structures. Pedagogically, it is characterized by processing and transmitting information through communication, explanation, recombination, contrast, inference and problem solving [50]. This perspectives includes constructivism and experiential/reflective positions where learning is considered as an iterative process of updating existing understanding with new information acquired through activity. Inside this perspective the most famous model is the Kob's cycle (figure 1.10). An experiential model where learning is view as an integrated process with each stage being mutually supportive of and feeding into the next. It is possible to enter the cycle at any stage and follow it through its logical sequence [41].

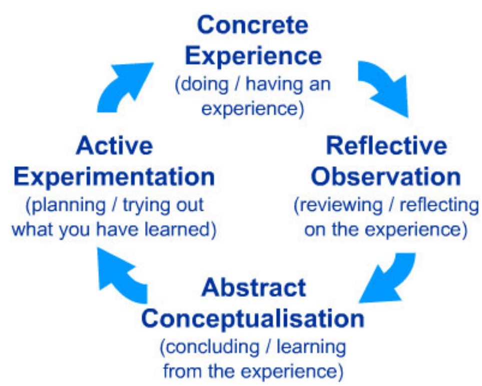

FIGURA 1.10. Kolb's learning cycle

- **Situative** The situative perspective views learning as social participation, and emphasizes interpersonal relationships involving imitation, modeling, and the joint construction of knowledge. It views the ultimate objective of learning as to enable us to experience the world as meaningful [50]. the characteristics of Situative view include (1) the concept that knowledge extends beyond the individual, and (2) the emphasis on perception (how individuals perceive the situation or the environment) rather than memory (how individuals retrieve knowledge)[3].

  One of the frameworks that supports the situative perspective is Activity theory (figure 1.11) which starts from the premise that activities occur within a context and that this context needs to be taken into account if we are to make meaning of the situation and appropriate interpretation of the results. It enables conceptualisation of both individual and collective practices in the wider socio-cultural context within which they occur. activity theory is most often used to describe activity in a socio-technical system as a set of six interdependent elements:

  - Object - the objective of the activity system as a whole
  - Subject - a person or group engaged in the activities
  - Community - social context; all people involved

- Division of Labor - the balance of activities among different people and artifacts in the system
- Tools - the artifacts (or concepts) used by subjects to accomplish tasks
- Rules - the code and guidelines for activities and behaviors in the system

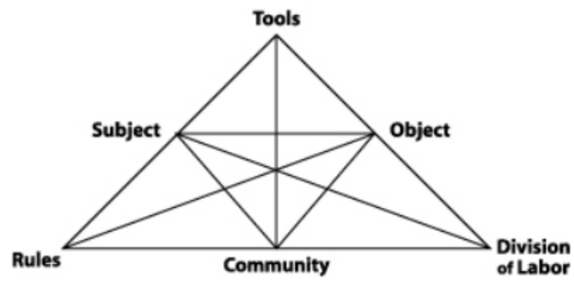

FIGURA 1.11. Model of an Active Theory system [20]

1.2.2. Augmented Learning

Augmented learning is defined as an on-demand learning technique where the learning environment adapts to the needs and inputs from learners it was proposed in 2008 by Eric Klopfer in the MIT Teacher Education Program [40]. Augmented Learning blends the cognitive and the situative learning perspective: constructing knowledge upon existing understanding via educational activities and its experience using real world context and a collaborative approach. "Leading to activities that that are inherently social, authentic and meaningful, connected to the real world, open-ended so they contain multiple pathways, intrinsically motivating, and filled with feedback". Augmented Learning uses Augmented Reality as main technology providing the following characteristics

- Authentic and Meaningful: Learning activities in real contexts connects them to actual people, places, and events. While the specifics of these activities may be fictionalized, basing them in the reality of physical places-through which the players must physically navigate-deeply connects the students to the problem and place at hand.
- Connected to the Real World: By using Augmented Reality many intangibles of the physical world get incorporated in the learning activities providing the opportunity of studying real world concepts than can not be easily explained.
- Open-Ended/Contain Multiple Pathways: The problems designed can use a real-world approach characterized by the lack of one clear answer. Students explore all the information and constantly redefine their own goals. In the end defending their answers and the means that they used to define that answer.
- Filled with Feedback: Feedback can come in many forms. The most obvious is directly by electronic means. As students physically interact they are provided with virtual feedback based on their actions, preprogrammed outcomes, and underlying models. But feedback can also come from other students. As students encounter each other, they exchange information and ideas, providing useful feedback to each other.

Tabla 1.1. Main learning perspectives approach and characteristics

Perspective	Approach	Characteristics
Asociative	Behaviourism Instructional design Intelligent tutoring Didactic E-training	Focuses on behaviour modification, via stimulus-response pairs. Controlled and adaptive response and observable outcomes. Learning through association and reinforcement.
Cognitive	Constructivism	Learning as transformations in cognitive structures.
	Reflective Problem-based learning Inquiry-learning	Task-orientated, self-directed activities. Learners build own mental structures. Language as a tool for joint construction of knowledge.
	Dialogic-learning Experiential learning	Learning as the transformation of experience into knowledge, skill, attitudes,and values.
Situative	Cognitive apprenticeship Case-based learning Scenario-based learning Vicarious learning Collaborative learning Social constructionism	Take social interactions into account. Learning as social participation. Within a wider socio-cultural context of rules and community.

TABLA 1.2. Main learning perspectives e-learning applications, models and frameworks

Perspective	E-learning application	Models and frameworks
Asociative	Content delivery plus interactivity linked directly to assessment and feedback	1. Merrill's instructional design principles 2. A general model of direct instruction
Cognitive	Structured learning environments (simulated worlds); Systems that guide users; Access to resources to develop more engaging authentic learning environments; Asynchronous tools synchronous tools richer forms of interaction;	3. Kolb's learning cycle 4. Laurillard's conversational framework 5. Community of Inquiry framework 6. Jonassen's constructivist model 7. n-Quire model
Situative	New forms of distribution offer potential for shared knowledge banks; Adaptation in response to discursive and active feedback Emphasis on social learning and collaboration; Access to expertise. Potential for enhancing existing communities	8. Activity Theory 9. Wenger's Community of Practice 10. Salmon's 5-stage e-moderating model 11. Connectivism 12. Preece's framework for online community

1.2.3. Blended learning

Blended learning is a formal education program in which a student learns at least in part through online delivery of content and instruction with some element of student control over time, place, path or pace cite.[24]

In blended learning, instructors use facets of self-paced instruction and live, collaborative learning to moderate the offline setting. This is also respectively known as asynchronous and synchronous learning. These methods of teaching and learning are essential in encouraging active participation in the blended learning environment [32].

1.2.4. synchronous learning delivery

This type of content delivery happens when the teacher and students meet at a physical or virtual class room an the same time, in person or using an internet videoconference. The synchronous experiences can be designed to develop and strengthen instructor-student and student-student relationships, which can be a challenge in distance learning programs [22].

1.2.5. asynchronous learning delivery

Asynchronous learning supports work relations among students and teachers when participants cannot be online at the same time. Asynchronous e-learning makes posible for learners to log on at any time and study the different topics and available materials[30]. allowing students to thoughtfully consider learning objectives because they have the time to critically synthesize their learning [24].

1.3. Learning strategies

Authentic activities engage the learner in a realistic and meaningful tasks that are relevant to the learner's interests and goals. By engaging learners in meaningful and relevant tasks, they can see the direct implications of their actions and apply the knowledge gained in real world situations [33].

In the third key component of the theory-based design framework proposed by Nada Dabbagh the following elements should be presented to enact authentic e-learning activities. [19]

- Using graphics to present elements of a case or problem to make it more realistic.
- Using animation to add context to the case.
- Developing a direct manipulation interface using web authoring tools to allow learners to immerse themselves in, and manipulate, certain aspects of the case environment.

The following are a set of learning strategies that can be applied in an Augmented Learning environment:

- FACILITATE PROBLEM-SOLVING, EXPLORATION AND HYPOTHESIS GENERATION

  Scenario problem based e-learning is mainly used at present in teaching subjects in the area of life sciences to deliver virtual lab experiments without the cost, time and safety constraints [8]. Augmented Reality has can been seen in the works proposed by can be a powerful tool for this kind of areas. Previous studies in literature have found that scenario problem based e-learning can help students learn course content and increase their motivation [8].

- SUPPORTING ROLE-PLAYING

  in role playing the students assume professional roles such as scientists, physicians, historians, salesperson, and other roles, in order to act out situations that these professionals face in the real life. Learners can imagine that they are other people in different situations then make decisions as situations change [28].

- PROMOTING ARTICULATION AND REFLECTION

  Articulation involves "having students think about their actions and give reasons for their decisions and strategies, thus making their tacit knowledge more explicit or overt"[33]. Articulation occurs when students have the opportunity to explain what they know and what they have learned. is in that moment when they articulate their knowledge to one another: sharing their perspectives and knowledge.

- PROMOTING COLLABORATION AND SOCIAL NEGOTIATION

  collaborative learning can be defined as a collection of activities that emphasize (1) joint construction of knowledge; (2) joint negotiation of alternatives through argumentation, debate, and other means; and (3) student reliance on both fellow students as well as teachers as learning resources. Therefore, social negotiation is an integral component of collaboration. [19]

- SUPPORTING MULTIPLE PERSPECTIVES

  This learning activity promotes the construction of flexible knowledge presenting multiple points of view of a subject, concept or events. Learners rearrange information to construct new knowledge, acquiring flexible and meaningful knowledge structures [18]. Basically this strategy consists in present the information in different ways so the students can create connections and their own explanations.

- SUPPORTING MODELING AND EXPLAINING

  Essentially, modeling shows how a process unfolds, while explaining involves giving reasons why it happens that way.Modeling and explaining of internal processes is an effective way to scaffold student's performance. By experiencing a teacher or expert's cognitive processes, students are better able to adopt the expert's mode of thinking [26].

- PROVIDING SCAFFOLDING

  Scaffolding is a concept proposed originally by Vygotsky [5] where the student should have supporting assistance during his learning process in order to achieve the proposed goals.

CAPÍTULO 2

EDUCAR FIRST PHASE

2.1. Introduction

This chapter describes the development and characteristics of EducAR (Educative Augmented Reality) a learning system designed for teaching in virtual learning environments using collaborative augmented reality in order to display and interact with 3D models of organic chemistry. This learning system enhances the educational experience in synchronous and asynchronous environments promoting the appropriation of new concepts. It is also explored the use of an interaction technique based on the Wiimote that improves the interaction between the user and the 3D generated content.

Educar learning system as described in the previous chapters has 3 main components: a learning application, a set of instructional activities and a pedagogic model as can be seen in figure (2.1).

The learning system is designed in two phases in order to evaluate in a more precise way the implications of the system in the educative process: in the first phase the focus is on the learning application and its components, the communication model and the interaction model. In this phase the communication model has a semi-collaborative p2p architecture this means that the communication is only possible between two participants. The roles of teacher and student are only determined by the real role of the person that used the application as no distinction is present in the software. Both participants have the same version of the application and the same interaction capabilities. Also in this phase the first version of the interaction model using the Wiimote is developed and tested.

In the second phase a new communication model architecture is developed allowing the simultaneous use of the application for 2 or more users. Also the roles of student and teacher are created: depending on the role, the version of the application has different functionalities. Allowing the creation of a full virtual classroom with one teacher and several students working and participating at the same time. its in this virtual classroom where the instructional strategies and the pedagogic model are in charge of a successful learning experience

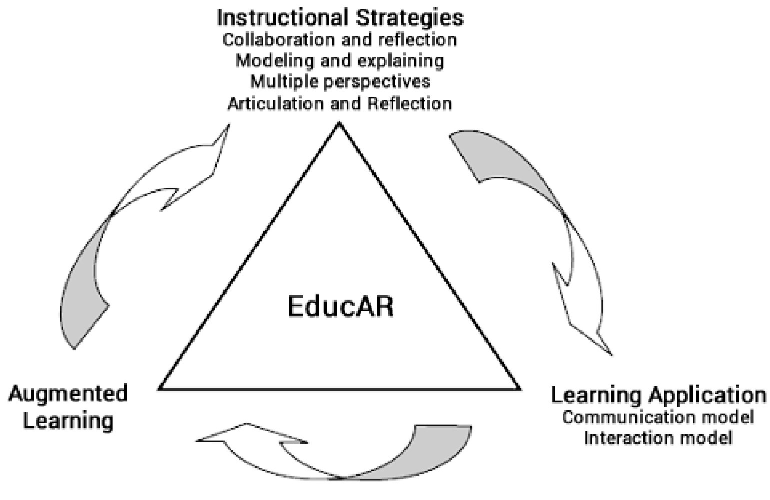

FIGURA 2.1. EducAR components

2.2. Description

For this research EducAR learning application is designed for teaching the subject of organic chemistry, focusing on the appropriation of concepts like introduction to organic chemistry, Lewis structure, isomerism and stereo chemistry Figure(2.2). EducAR can be used in synchronous, asynchronous education and in personal or collaborative way. In this first approximation the communication process can only be established between 2 persons that could be a teacher and a student or both students.

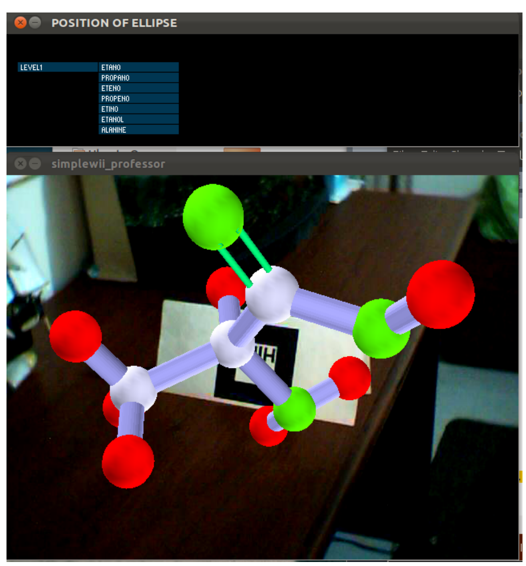

FIGURA 2.2. An Alanine molecule view in EducAR

2.2.1. Sinchronous Model

The teacher does his lesson and this is transmitted to the student using video conference. teacher and student can see and communicate constantly with each other but they also share the 3D models created with augmented reality: the changes made by the teacher (selection, rotation, zoom) in his model are reflected in the student's model. The students can select an atom in particular to expose some doubt and this selection is reflected in the teacher's model To facilitate the interaction and improve the lesson flow, the teacher can control all the 3D models and develop his lesson only with the Wiimote, without the need of interact with the computer directly, allowing hi to perform the operations of zoom, 3 axis rotation, selection of a particular atom or element inside the model and change the model.

2.2.2. Asynchronous Model

The student can perform an autonomous and independent learning process without the supervision of a teacher, interacting with the chemistry 3D models preloaded in the system. the student can perform the operations of zoom, 3 axis rotation and selection of atoms or elements in particular to get more information about them. To interact with the system the student can use the conventional media (mouse and keyboard) or a Wiimote if has the availability.

The following architectures are designed to keep low costs, so the application can be implemented in any educative center and have an easy integration with the current hardware

2.2.3. Architecture

For the asynchronous model the hardware architecture consists in 2 computers interconnected by an UDP connection. This connection protocol was chosen over the The most common TCP protocol for the following reasons:

- There is no need to maintain connection state in the end systems(ie no need for send and receive buffers,congestion control parameters and sequence and acknowledgement number parameters) hence more active clients could be supported
- UDP provides better application level control over what data is sent since the data is packaged in a UDP segment and immediately passed over to the network layer hence no-frills segment delivery service is observed.
- There is no need for connection establishment hence no delay(unlike TCP which requires handshaking before the actual data transfer)
- Small packet header overhead for UDP(only 8 bytes) where as TCP has 20 bytes of header
- Its use will allow in the next phase to implement a multicast connection in order to increase the number of users

Each computer has 2 web cameras: one camera is used for the augmented reality marker recognition and the other for the videoconference between the student and teacher. the connection between the Wiimote and the computer is done by bluetooth. In order to use the Wiimote as a mouse an infrared led connected to a protoboard is needed, the Wiimote camera only recognizes infrared light in order to eliminate coordinate estimation errors created from the several sources of light that can be in a room, (figure 2).

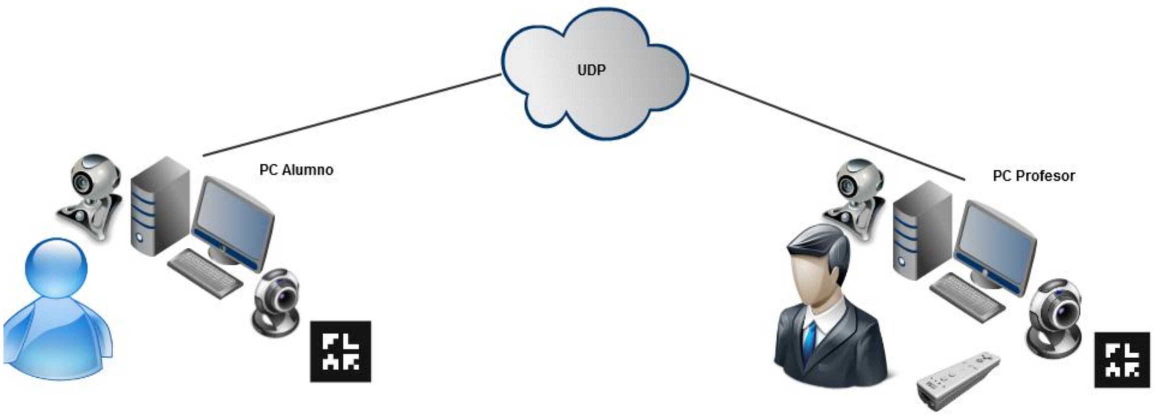

Figura 2.3. fig. 2. Synchronous model architecture, student in the left teacher on the right

The architecture for the asynchronous model consists in one computer and one webcam used for the recognition of the augmented reality marker. with this components the student can check the lesson material and interact with it from his home. In both architectures the use of the Wiimote is optional for the student, the system is designed in a way that can be used with mouse and keyboard only, but as it will be shown its use is recommended (figure 3).

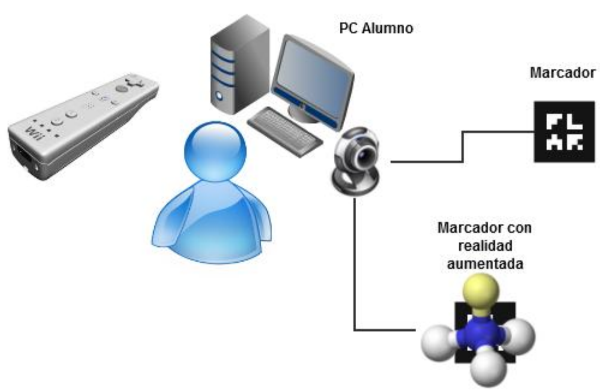

Figura 2.4. fig. 3. Asynchronous model architecture

2.2.4. Software

The selected programming language for the development of EducAR is Java/Processing. This language is chosen due to the nature of the project that needs a lot of graphic capabilities such as: the ability to create interactive programs with 2D, 3D, OpenGL integration for accelerated 3D support and open source and community support.. In order to use marker based augmented reality the augmented reality library selected is NyARToolkit [54] which is a set of libraries and classes created from the C/C++ ARToolkit framework [37] that allow the recognition and tracking of simple black and white markers with great precision. For the internal control of the Wiimote accelerometer and its infrared camera the processing library Wrj4P5 [15] is used. implementing the necessary mechanisms for control, interaction and events, in order to create the relation between the Wiimote's movement and buttons with the desired actions in EducAR. To develop the exchange of messages between computers via the UDP protocol the library Hypermedia [17] is used. The datagram is created and filled during the program execution and is send each time an user event happens, the UDP connection is always listening so when a new datagram arrives the actual coordinates and elements in the model are updated. So each change in the teacher's or student's 3D model is reflected in the other's model. Generating a collaborative interaction between the participants.

2.2.5. Organic chemistry models

The 3D models used in EducAR are created using the adaptation of the Jmol library [29] for processing. This library allows the displaying of molecules and compounds using 3D primitives like spheres and tubes. Taking the information of the atom connectivity and 3D coordinates from .mol plain text files. Thanks to this EducAR can graphic almost any reported molecule or compound, from simple molecules of a few atoms, until long organic chains, without its performance being affected. This feature also eliminates the need of External software to design every model. The teacher only needs to search and download the .mol file of the desired molecules and put them in the EducAR resources folder. facilitating the lesson preparation for the teacher.

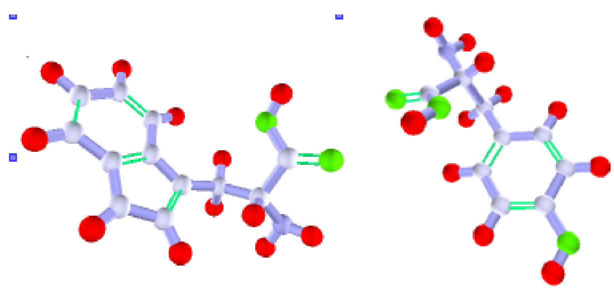

FIGURA 2.5. example of the molecules that can be modelled by EducAR

2.2.6. Interaction

The designed user interaction model is intended to manipulate the generated 3D models in a practical but yet entertaining form. The objective is to take the student attention inviting him to explore the presented concepts improving its appropriation. To achieve this the following interaction mechanisms are defined:

– Rotation: using the Wiimote accelerometer the 3D models can be rotated independently in the 3 axis, each axis has a different gesture and there is a common position where there is not any rotation in order to avoid undesired mistakes. The rotation starts when the Wiimote is rotated 90 degrees in the desired position as is indicated in figures 2.6,2.7,2.8. Once the Wiimote is located in the position the 3D model will rotate constantly until the position is changed, placing the Wiimote in the opposite position will generate a rotation in the negative direction.

a b c

FIGURA 2.6. Model rotation in the X axis a) rotation on positive direction b) neutral position c) negative direction

a b c

FIGURA 2.7. Model rotation in the Y axis a) rotation on positive direction b) neutral position c) negative direction

a b c

FIGURA 2.8. Model rotation in the Z axis a) rotation on positive direction b) neutral position c) negative direction

- Selection: Using the infrared camera placed in the Wiimote the light generated from an infrared led can be distinguished, obtaining the led's coordinates respect from the Wiimote camera. This coordinates can be converted into 2D coordinates in a range that corresponds to the window size of the application, in order to move the mouse pointer to this coordinates emulating the movement of a mouse. By doing this constantly, a good mechanism to move the mouse pointer with the Wiimote is obtained, this mechanism is very stable and presents an approximate range of one meter using only one infrared led (figure 2.9). To make the click action the B button of the Wiimote is used, which is ergonomically appropriated for this action.
- Zoom: using the accelerometer inside the Wiimote, the actual orientation of the controller can be determinated and used to know if the Wiimote is in vertical or

FIGURA 2.9. Selection with the Wiimote by pointing to a set of infrared leds

horizontal position. This can be used to create a gesture to efficiently increase or decrease the zoom of the molecule: if the Wiimote is in Horizontal position the zoom will increase and decrease if it's in vertical position while describing and arc.

FIGURA 2.10. Zooming with the Wiimote

2.3. Evaluation

A between subjects user test is conducted with 20 user from both genders with an age between 21 and 36 years, the users explore the system for 1 minute and after that they participate in a short 5 minutes lesson. During this lesson the concepts of chemical bond, simple, double and triple bond, nomenclature and alcohol formation are explained using EducAR in a synchronous way. The students interact with the teacher by videoconference, while at the same time they could manipulate the molecular 3D models. A group from the students interact with the system using the Wiimote and the other using mouse and the keyboard. After that all the students answer three questions of organic chemistry from the topics explained during the lesson, and take a short survey about their experience with the system where they grade from 1 to 10 the following aspects: performance, entertainment, utility, rotation easiness, selection quality, zoom, pertinence and necessity.

For this test 2 computers with the following characteristics where use Processor: Intel core 2 duo Ram: 2GB Integrated graphic card Dell mini from 2005 model Web camera: genius Look 317 2009 model

2.4. Results

Below is presented the average results of the survey performed by the 20 participants and the percentage of correct answers (table 2.1) the results are from 1 to 10 being 1 the worst and 10 the maximum

Tabla 2.1. User test results

	Wiimote	Mouse - teclado
Desempeño	7.4	7.2
Entretenimiento	7.8	6.6
Utilidad	9.2	8.4
Facilidad rotación	7.4	6.4
Facilidad selección	8.0	8.0
Facilidad zoom	6.6	8.2
Pertinencia	7.5	7.4
Necesidad	8.8	8.1
Preguntas correctas	91.6 %	80 %

As it can be determinated from observing the components of performance, utility and necessity, in most of the cases users prefer to use EducAR using the Wiimote instead of the system with keyboard and mouse. except the zoom action that several users did not find pleasant. This action will be evaluated and changed in the next phase. Additionally the students despite of had only a 5 minutes lesson got very good marks in the organic chemistry questions. the users that interacted with the system using the Wiimote got 91.6 percent of good questions while the ones that interact using keyboard and mouse got 80 percent of good questions. both percentages are high enough to demonstrate that the application helped the group to appropriate the new concepts. The results for the Interaction using keyboard and mouse show that the application can be used with the conventional interaction techniques, although does not show to be as entertaining as using the Wiimote. This is a fact to be taken into account because the application main public are students from high school and first semesters of college, which some times need to be motivated in order to explore the lessons materials

The creation of an application that uses a communication model for virtual education using collaborative augmented reality and an interaction technique based on the Wiimote was well received by the students. As expressed in the review the students could feel that the concepts were more close and accessible, increasing their interest for the subject. Also in the review was indicated that the use of the Wiimote facilitates the interaction with the 3D models, specially rotation and has a similar capacity that the mouse. Additionally the systems guarantees low costs because can be used from most of all actual computers and conventional web cams without performance problems and the necessity of external components is minimal (web cam, paper markers). The use of the Wiimote is optional but is desirable, however other interaction techniques can be investigated that do not generating additional costs while creating an entertainment level equal or similar

2.5. User feedback

from the feedback given by the students and the user test results, its considered necessary to redesign the zoom mechanisms with the wiimote. implementing other gesture or using the buttons in the Wiimote. Additionally it would be recommendable to try the EducAR application in other environments and scenarios: autonomous asynchronous education, synchronous education but with multiple students connected at the same time and in class education using EducAR as a multimedia complement to the lessons

Some concepts of this chapter were published in the article entitled "Ambientes Educativos Virtuales Con Interacción basada En Realidad Aumentada Usando El Wiimote" presented at ticEDUCA 2012 II Congresso Internacional TIC e Educação [47]

2.6. Summary

In this chapter the following topics were covered

- The presentation of EducAR and its components
- The synchronous and asynchronous content delivery modes
- The communication model architecture for both content delivery modes
- The EducAR software components and libraries
- The interaction model using the Wiimote
- The first user evaluation

CAPÍTULO 3

EDUCAR SECOND PHASE

3.1. Introduction

This chapter describes the development and characteristics of EducAR (Educative Augmented Reality) second phase. as was said in the previous chapter EducAR is an learning system designed for teaching in virtual learning environments, using collaborative augmented reality in order to display and interact with 3D models of organic chemistry. This system enhances the educational experience in synchronous and asynchronous environments promoting the appropriation of new concepts.

This phase is focused on improving the distributed and collaborative functionalities of EducAR, and to implement the proposed learning components that complete the learning system: the pedagogical model and the learning strategies. The following improvements are made during this phase.

1. Implementation of a UDP broadcasting connection that allows the participation of several students and one teacher at the same time.
2. Two versions of the application are created: one for the students and one for the teacher. Both with different user interfaces and functionalities.
3. New molecules are added in order to provide the opportunity of teaching new concepts like isomersism and stereochemistry.
4. Creation of a Distributed questions and answers functionality in the synchronous mode: the students can formulate questions to the teacher at any time during the lesson. Those questions can also be seen by all the participants.
5. Changes in the interaction model based on the feedback received during the first phase.

3.2. Delivery content modes

EducAR was designed to have the two modes for content delivery synchronous and asynchronous, so depending on the class design any of them could be used, or both as a blended learning system.

3.2.1. Synchronous mode

In the class room Educar can be a way to enrich the and facilitate the class dynamics. Showing Augmented reality contents that can be manipulated by all students using the free interaction mode previously described. The level of interaction that the Augmented contents have makes the class more interesting and comfortable to the students. reducing the level of distraction and improving the appropriation of the concepts. Also the teacher can use EducAR as a presentation tool using the Wiimote to interact with the 3D models without requiring to interact with the computer, increasing the attention of the students to the concepts that are being taught.

In a virtual class room EducAR provides the necessary tools to create a grateful learning experience, allowing the total exchange of multiple ideas and concepts between the participants. The changes in the studied model made by the teacher are propagated to all the students that are in the virtual class room so every participant shares the same state (3D model, coordinates, selected atoms, scale). The student can also make questions at any time during the lesson. EducAR provides a notification and a turn based system that allows the teacher to answer each question whenever he wants. Those answers are also propagated to all the students. making the class more dynamical and interesting

3.2.2. Asynchronous mode

EducAR can be used in offline mode, as a complement for a learning management system like Blackboard or Moodle or simply as an additional material. Students can consult and interact with the augmented reality models and concepts at their own peace. With the freedom to access the course and its instructional materials at any time they choose, and from any location.

3.3. Augmented Learning

As was explained on the previous chapters the selected pedagogical model was Augmented Learning, a new pedagogical model proposed on 2008 by Eric Klopfer in the MIT Teacher Education Program. This model implements augmented reality to create lessons that are realistic, meaningful and with a real world approach. By using and approach with the following characteristics 1) the learning is interactive, 2) the teacher has a constant dialogue with the students, 3) the materials can be manipulated in in different ways, 4) knowledge is seen as dynamic and ever changing, 5) the tasks during the class include observations, points of view and simulations. EduAR applies this pedagogical model by its interaction and communication model, developing the needed resources and mechanism to apply the following instructional strategies:

3.4. Instructional Strategies

Instructional Strategies are the application of the pedagogic model in the classroom so they are the core of any instructional and learning activity. Following is the description of this learning activities that can be found in EducAR:

- FACILITATE PROBLEM-SOLVING, EXPLORATION AND HYPOTHESIS GENERATION

  The use of augmented reality in EducAR can be used for problem solving based learning, allowing students to immerse themselves in a realistic working environment where the situations require them to apply and develop their knowledge and problem solving skills. Authentic scenarios can help students appreciate the practical applications of knowledge and develop a deeper understanding of concepts studied.

  EducAR gives students a variety of options to explore realistic situations using Augmented Reality. Students are given greater control of their own learning, as they can see the consequences of their own actions and decisions when working with the material. Also, feedback can be provided on their actions while they work through the problem.

- SUPPORTING ROLE-PLAYING

  By using Augmented Reality a set of 3D models can be designed to act as to role-playing instruments e.g mechanical instruments, dentist instruments, pieces of a engine and tools for a certain job. Which can be used to create real life situations where students can perform different roles. Also EducAR thanks to its communication model can be used to facilitate the work withing groups, by forming teams Making the role-playing more entertained.

- PROMOTING ARTICULATION AND REFLECTION

  EducAR in its synchronous mode promotes and facilitates the articulation of concepts. Students can share their perspective and their ideas to everybody no matter if they are in the same class room or they are in different locations. In the communication model the teacher becomes a facilitator rather than only the presenter of the contents.

- PROMOTING COLLABORATION AND SOCIAL NEGOTIATION

  EducAR extensively promotes the collaboration between students. And helps the teacher to propose several activities that foster the teamwork e.g: online group discussions on a particular topic, organize tasks where team members must cooperate to achieve a certain goal, and engage students in communication and discussion activities. As EducAR can be used synchronously by a group of students without the teacher being present those activities can be also proposed by students themselves

- SUPPORTING MULTIPLE PERSPECTIVES

  The 3D augmented reality models used by EducAR can be designed in different ways so they can represent different points of view of the same concept e.g physical structure, internal and external properties, linked connections. Etc. By using the interaction model these points of view can be easily manipulated: rotated and zoomed, so the student could have a better understanding of the point of view presented.

- SUPPORTING MODELING AND EXPLAINING

  One of the properties of augmented reality is that it can combine different types of information into the same 3D model showing the event and the explanation at the same time. for example in EducAR when a molecule is selected a 2D version of the nomenclature using Lewis structure appears, showing some relevant information about it.

- PROVIDING SCAFFOLDING

  In big class rooms or in asynchronous e-learning this is a challenge due to the number of students and the different levels of experience they have. EducAR collaborative model can be a way to tackle this challenge: more experienced students can help other students even if they are geographically separated. Also the teacher or class monitors can organize sessions to help and clarify doubts to large groups of students using EducAR's question - answers turn based system. Also some 3D tutorial models can be designed to help the students in a asynchronous way.

3.5. UDP message transmission

UDP Multicast is a technique for one-to-many or many-to-many (like in this case) real-time communication over an IP infrastructure in a network. It allows a process to contact multiple hosts with a single packet, without knowing the specific IP address of any of the hosts. The nodes in the network take care of replicating the packet to reach multiple receivers such that messages are sent over each link of the network only once.

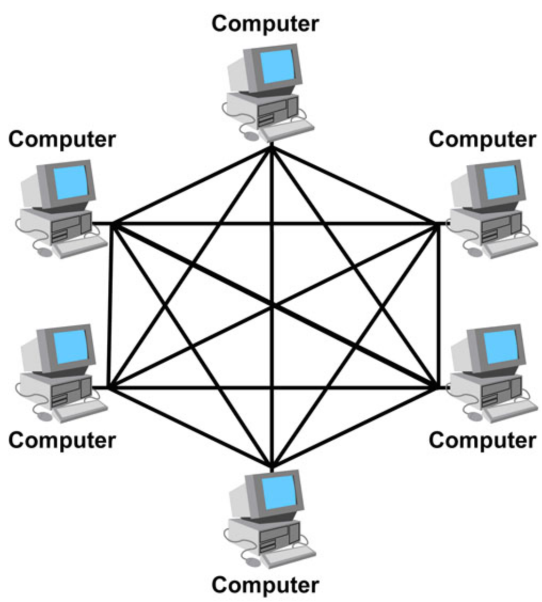

FIGURA 3.1. UDP multicast

Multicast datagrams are sent to special multicast group addresses (in the IPv4 range 224.0.0.0 to 239.255.255.255), along with a corresponding port. In order to receive multicast datagrams, the user must join that specific group address. Just like being in the same class room. Datagrams are similar to passing notes in the classroom. Each note is self-contained, having the destination and source addresses and the body of the message. In the organic chemistry example the datagram consists in eight values that contains the actual state of the 3d model: X Y and Z coordinates, atom selected, molecule name, ip and name of the participant. And the message that has to be sent e.g "I have a question", "ok its your turn you can make your question". This datagram is sent each time an event occurs in order to replicate this even to every participants

Using this system a communication really similar to the real life can be established, where a teacher communicates ideas and concepts and is being heard by students. Also students can formulate questions that can be listened by everybody. The question request that the student sends is like if he raises his hand and waits for his turn until the teacher let him ask the question

UDP Header		UDP MESSAGE								
Source	Destination	0	1	2	3	4	5	6	7	8
port	port	sign x axis	Increment X	sign y axis	Increment Y	IP question	IP answer	Zoom	sign zoom	molecule ID

FIGURA 3.2. UDP multicast datagram

3.6. User roles and functionalities

Apart from the functionalities developed in the first phase: rotation in the three axis, zoom, specific atom selection, two user roles are created: students and teacher. Although both roles have the same core functions they diverge from each other by having different functionalities

3.6.1. Student functionalities

- **Send question to teacher:** At any moment the student can press the "I have a question" button. Educar will display a message indicating that the question was sent and that must wait his turn. When the teacher authorizes, the student will receive another message, from that moment every interaction and change in the model that the student makes will be sent to every participant in the class
- **Activate free mode:** This mode blocks the reception of events from other participants so the student can explore the model at his own peace. At any moment the student can recover the actual state of the class, the system will reacomodate the model: coordinates, zoom and selected atoms to the actual state of the class.

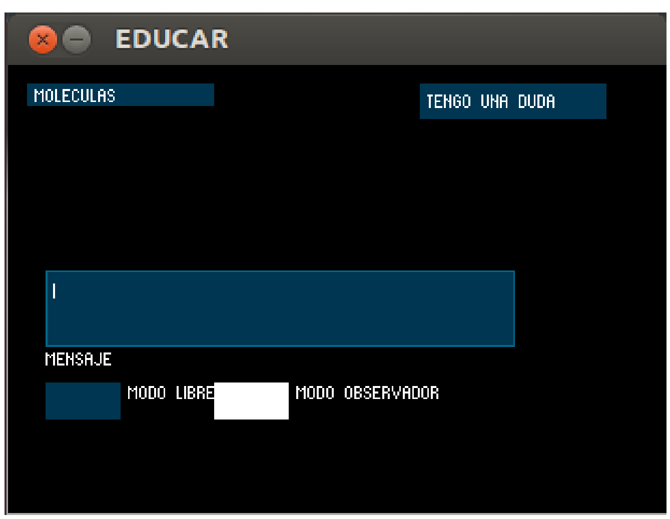

FIGURA 3.3. Student user interphase

3.6.2. Teacher functionalities

- **Answer student's questions:** When a student sends a question request, the system shows its name and ip direction. by clicking on it the teacher authorizes the student to formulate the question. Educar manages a turn based system when more than one question arrives, so the teacher can decide the correct moment to answer them. When the student ends the question, the teacher interacts with the model to answer it. This interaction is reflected in all students model to make the process more similar to reality. After the answer is finished the teacher returns to the state that the model had before the question by clicking the "return to class" button.

- **Send the start class instruction:** When the teacher starts to manipulate the model an additional instruction is added to the datagram and sent to all the participants. This instruction activates the class mode: the model state is synchronized for all students for the first time.

- **Change molecule:** during the class mode only the teacher can change the model that as has been said is shared by all students. Selecting one new molecule from the drop down list. in order to avoid misunderstanding between students that changed the molecule in a local way.

FIGURA 3.4. Teacher user interphase

3.7. Interaction model

In order to improve the interaction model presented in the phase one the following changes were made, based on the observations and the feedback provided by the users:

- **Changes in the zoom functionality for the Wiimote interaction technique:** in the feedback received by the user test on phase one several users express that the zoom gesture was very difficult. To execute this action the user needed to raise or descend the control describing and arc with his arm to increase or reduce the zoom of the molecule. to improve this action the physical buttons of the Wiimote are used: The user only has to press the + or - button to increase or reduce the zoom.

- **changes in the controls for rotate the molecule:** in order to increase the usability of the app another set of keyboard keys is added. in the phase 1 the users controlled the model using the WASD set of keys: a and d for the X axis rotation and w and a for the Y axis. those keys are the most used for gaming control but in order to allow another option for non experienced users the model can now be controlled also using the arrow keys

3.8. Chemistry application

As was explained on the previous chapter in order to test in a real scenario the EducAR learning system, the learning application was adapted to teach the concepts of organic chemistry specially its nomenclature and the main characteristics of the basic compounds: alkanes, alkenes and alkynes, alcohols . On this second phase a new set of 3D models is constructed in order to teach the concept of isomerism. Also a user test is conducted in order to evaluate the learning application, the pedagogic model and the learning strategies previously explained.

3.8.1. isomersism and stereochemistry

In chemistry, isomers are molecules with the same molecular formula but different chemical structures. This means that isomers contain the same number of atoms of each element, but have different arrangements of their atoms in space [57].

Stereochemistry, a sub discipline of chemistry, involves the study of the relative spatial arrangement of atoms that form the structure of molecules and their manipulation. An important branch of stereochemistry is the study of chiral molecules. Stereochemistry is also known as 3D chemistry because the prefix "stereo-"means "three-dimensionality"[49].

As can be seen the contents of this disciplines can be beneficiated from the use of Augmented Reality in its learning process. So for this reason several molecules of structural isomers and stereoisomers are included. By using EducAR students can manipulate and see those molecules from different points of view, studying their atoms and the geometrical relation between the atoms and the functional groups.

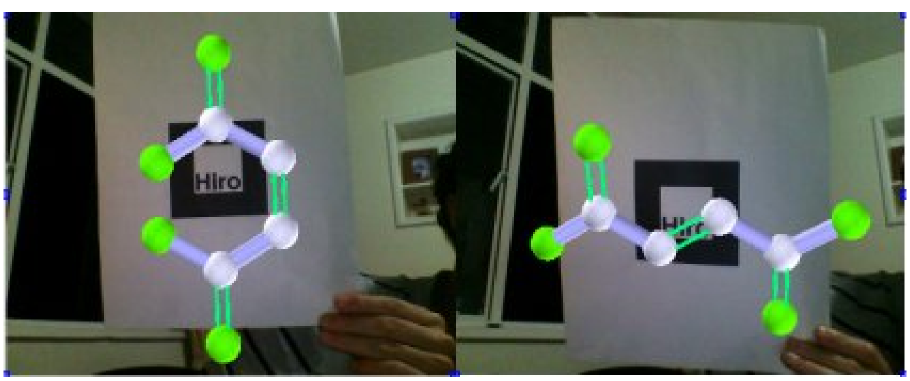

FIGURA 3.5. 2 isomers in EducAR

3.8.2. Evaluation

A between subjects user test is conducted with 20 user from both genders with an age between 18 and 25 years. The users are students from different engineerings most of them from the first semesters. The users explore the system for 5 minutes and after that participate in a short 10 minutes lesson. During this organic chemistry lesson the concepts of chemical bond, simple, double and triple bond, nomenclature, alcohol formation and structural isomerism are explained by the teacher using EducAR in a synchronous way. The following three main parts of the e-learning system are tested:

- **P**edagogical models and Instructional Strategies:The class is designed following the principles of Augmented Learning: using interactive materials that are connected with the real world, providing constant feedback through the system and the teacher, allowing a constant interaction between the participants and asking the point of view of the student.

  From the instructional strategies previously explained the following instructional strategies are used during the class: Promoting articulation and reflection, promoting collaboration and social negotiation, supporting multiple perspectives and supporting modeling and explaining

- **I**nteraction model: During the class the students could manipulate the molecular 3D models to explore the models at their own peace in order to explore the details of the lesson, by making local changes like rotation and zoom using their assigned interaction technique: mouse - keyboard or Wiimote.

- **C**ommunication model: The student communicate with the teacher face to face and using EducAR in a synchronous way: all the changes in the models done by the professor where transmitted to all the students so every participant shares the same view of the model and lesson.

  The question and answer part of the communication model is also tested, students are invited to make questions at any time during the lesson. Every time the student made a question the teacher receives a notification so he could authorize the student. When authorized the student acquires the capacity of sending their changes in the model to all the participants, so everyone can see the question.

Due to a limitation in the number of computers the test is conducted in groups of 6 students, so it is necessary to conduct 4 test. During those tests a group of the students interacts with the system using the Wiimote and other using the mouse and the keyboard. After that each student answers 4 multiple choice questions of organic chemistry from the lesson topics and takes a short survey about their experience with the system. Participants grade from 1 to 10 the following aspects: performance, entertainment, utility, rotation easiness, selection quality, zoom, pertinence and necessity.

For this test 6 computers with the following characteristics are used:

4 PC Processor: Intel Pentium 4 Ram: 1.5GB Integrated graphic card Dell blabala from 2011 model Web camera: genius Look 317 2009 model

2 laptop

Processor: Intel core i3 Ram: 4GB Integrated graphic card HP G42 from 2010 model Web camera: laptop integrated

Processor: Intel core i3 Ram: 4GB Integrated graphic card Dell latitude from 2009 model Web camera: laptop integrated

A group of 10 students also works as control group, taking a paper-based version of the lesson with the same script used by the teacher, along with the same pictures that are presented in EducAR. After studying the material they answer the same questions about organic chemistry. They do not know about EducAR and its interface so the do not answer the qualitative survey.

3.8.3. Results

Below is presented the average results of the survey performed by the 20 participants (table 1) the results are from 1 to 10 being 1 the worst and 10 the maximum

Tabla 3.1. survey results of the two user groups

	WII	Variance	Mouse - keyboard	Variance
Performance	8.8	0.918937	8.6	1.264911
Entertainment	9.7	0.674949	9.7	0.483046
Usefulness	9.3	1.159502	9.0	1.414214
Rotate operation	8.5	1.080123	7.9	1.852926
Zoom operation	9.2	1.316561	8.3	2.162817
Relevance	9.5	0.527046	9.1	0.994429
Necessity	9.2	1.0322796	9.1	1.197219
Help for home studying	9.5	0.707107	9.3	1.05935

The results of the questions answered by the 3 groups: paper based, students that interacted with the models using the Wiimote and students that interacted with the models using mouse and keyboard, are showed as follows:

Tabla 3.2. Organic chemistry test results

	wii	mouse keyboard	paper based
Question 1	8	8	7
Question 2	9	9	8
Question 3	9	8	5
Question 4	7	6	3
Correct answer percentage	82.5	77.5	57.5

As can be seen from observing the components of performance, utility and necessity, in all of the cases users prefer to use EducAR using the Wiimote instead of the system with keyboard and mouse. The use of the Wiimote helped students to interact with the system in a easier way and to focus their attention in the lesson and concepts and not in the how to interact with it, as was seen students did not even have to look at the Wiimote to control the 3D models.

Interaction using keyboard and mouse show show that the application can be used with the conventional interaction techniques although as expressed by the students did not show to be as entertaining as using the Wiimote, however they also expressed that if they had the opportunity to use the system at home, they will use it using the mouse and keyboard.

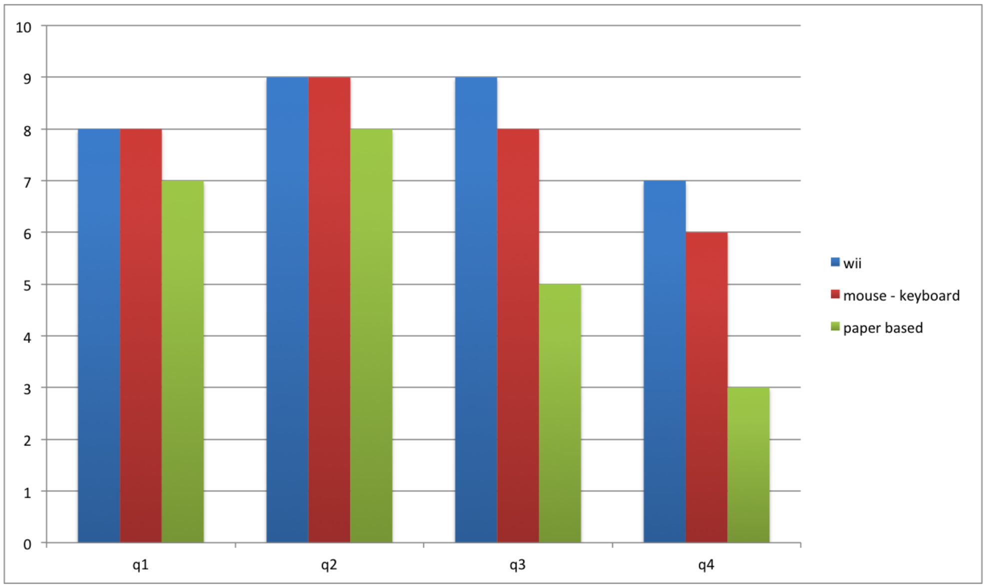

FIGURA 3.6. Questions results

Additionally the students despite of had only a 10 minutes lesson and that several concepts were introduced: organic chemistry nomenclature, alkane, alkene and alkyne molecules and structural isomerism got very good marks in the organic chemistry questions. the users that interact with the system using the Wiimote got 82.5 percent of good answers while the ones that interact using keyboard and mouse got 77.5 percent of good answers. both percentages are high enough to demonstrate that the application helped the users group to appropriate the new concepts.

The Fact that the control group got 57.5 percent of right answers could show that the use of non common interaction techniques and innovative delivery content methods like augmented reality are suitable for the educative field. But in order to accept this a assumption a more detailed statistical test must be done.

3.8.4. Statistical analysis

In order to compare the three groups and to confirm the assumption that the use of EducAR improves the appropriation of new concepts and that this was reflected in the results in organic chemistry, the three different user groups must be studied using a statistical test. In the first place the normality of the data must be checked, in order to do this two types of evaluation can be done. The first one is a graphical, using a histogram of the data. As can be seen this data does not follow a normal distribution

Also in order to statistical confirm the not normality of the data a Shaphiro-Wilk test was conducted, obtaining a p-value = 0.001383. This rejects the null hypothesis that the data was taken from the normal distribution.

Due to the not normality of the data a non-parametric test must be used. The Kruskal-Wallies was chosen because it can be used for data that contains two or more between subjects groups, also because is the non-parametric version of the ANOVA test which is highly used in human computer interaction and usability tests. When the Kruskal-Walis

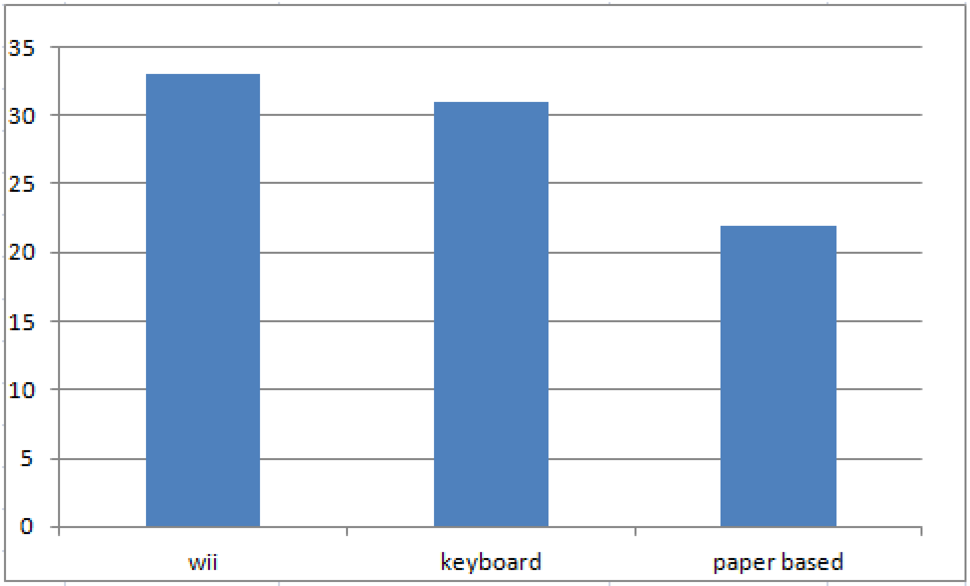

FIGURA 3.7. Right questions answered histogram

test leads to significant results, then at least one of the samples is different from the other samples.

The test was conducted using the number of correct answers of every student separated by the interaction form of each group

TABLA 3.3. Right answers by student

wii	keyboard	paper based
4	3	3
2	4	3
4	3	3
2	4	1
4	3	1
2	2	3
4	3	1
4	2	2
4	4	3
3	3	2

The data was organized in a list of 30 positions and the test was conducted using the statistical software R

The result was the following:

Kruskal-Wallis rank sum test

data: Value by Group Kruskal-Wallis chi-squared = 6.1694, df = 2, p-value = 0.04574

obtaining a p-value of 0.04574 which is less than 0.05 so the hypothesis is accepted, there is a statistical difference between the 3 studied groups

This can be also seen in the following boxplot graph 3.8:

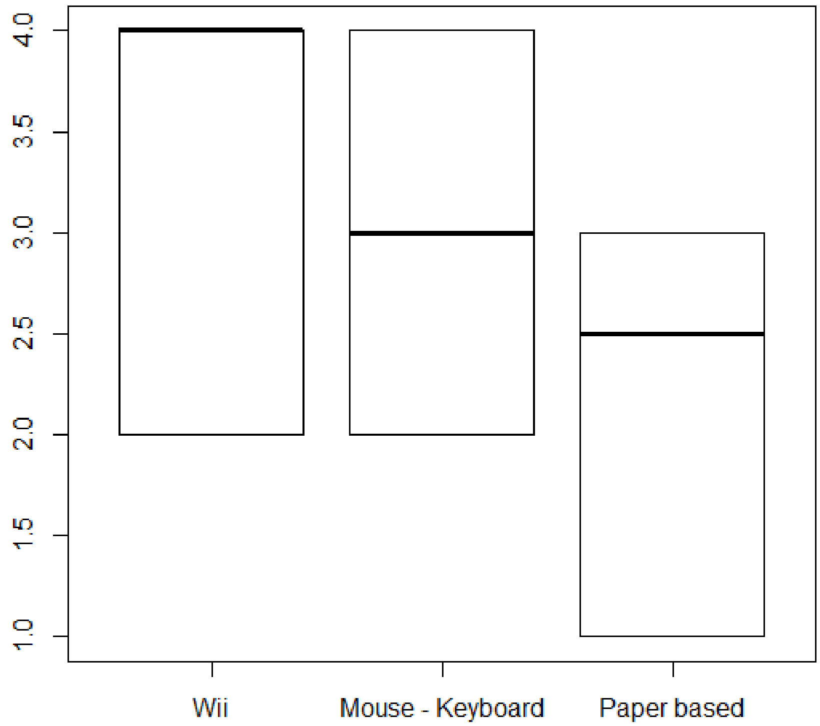

Figura 3.8. Boxplot of the 3 study groups

The results of the qualitative survey answered by the participants where converted into a Likert scale in order to be easily compared 3.9

3.9. User feedback

The users had the opportunity to add comments at the end of the survey, expressing their opinion and ideas about the system. The comments were very positive about the application and its qualities for educative content deliver. Some of the opinions were about giving more functionalities to the mouse interaction, providing the option to make zoom with the scroll wheel and a mechanism to also move or rotate the models just with the mouse. Also the users express the necessity of showing more chemistry related information like reactive moment, dipole moment and electronic density. Other users present the idea of showing the process of chemical reactions using augmented reality by showing multiple molecules and using multiple markers.

3.10. Summary

In this chapter the following topics were covered

- The presentation of the second phase of EducAR
- The new delivery content modes

- The learning activities supported by Educar
- The communication model structure using UDP messages
- The users roles and interfaces
- The changes in the interaction model
- The Evaluation of the system

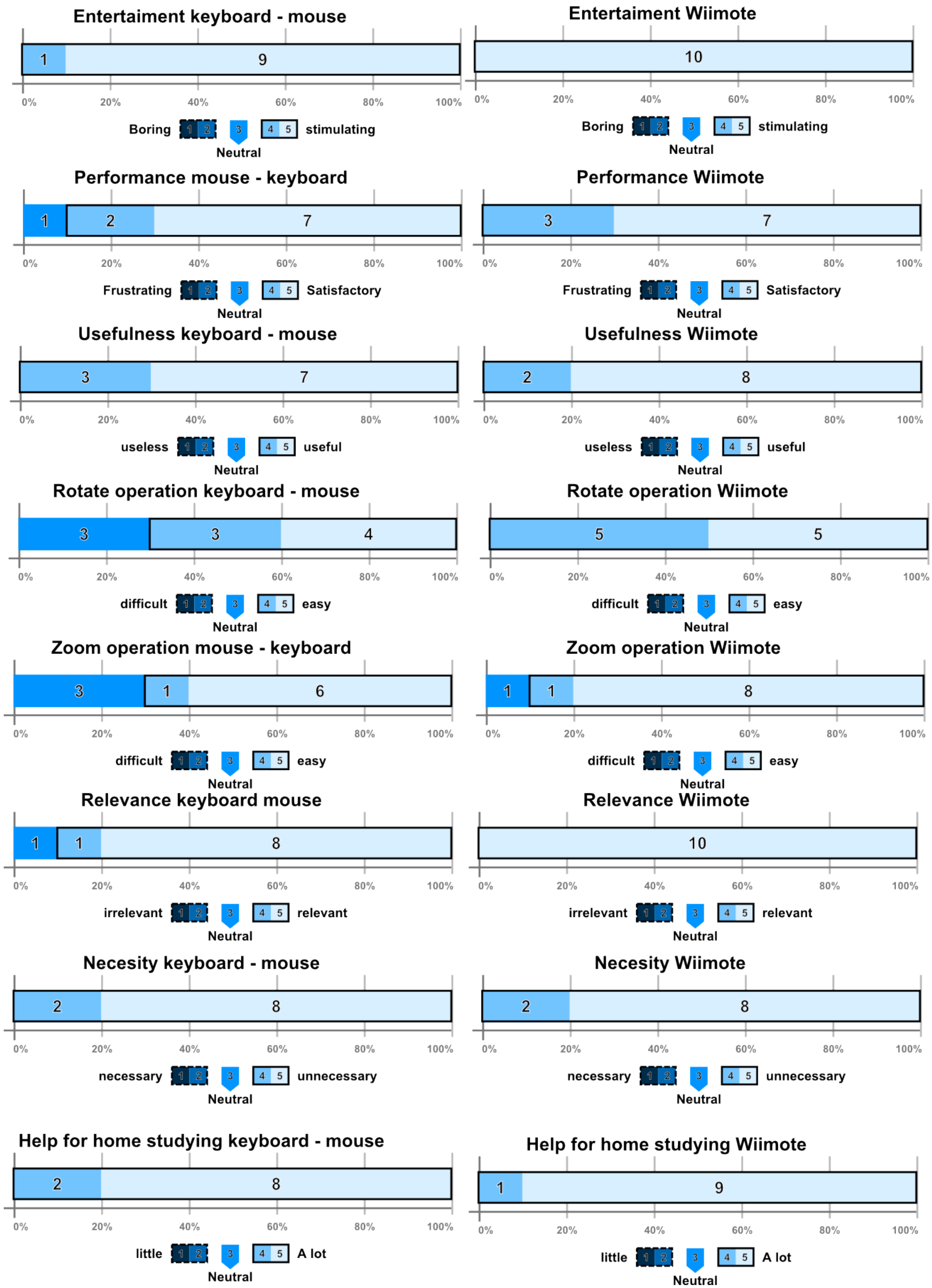

FIGURA 3.9. Survey questions answered

Conclutions

- The integration between pedagogy and systems engineering was the key factor during the design and development of EducAR, the reviewed literature always said that both disciplines should be together in order create a successful learning system, however how to do this was not very clear, until the Pedagogical Models for E-Learning design framework proposed by Dabagh was found. As was explained on previous chapters this methodology shows how to link a learning application with a pedagogical model through a set of instructional strategies. After reviewing the most recognized pedagogic models the Augmented Learning pedagogic model was chosen, based on its characteristics and the use of augmented reality in the educational field that this model proposes. Although, there is a small amount of literature about this pedagogic model, it is based on two of the most famous learning perspectives: the cognitive and the situative. This fact guided the construction of the instructional strategies following the ideas and principles of both models, but focusing on the activities that could be performed by using Augmented Reality as instructional technology. As the instructional strategies were proposed after a review of the literature they are not the only ones that can be used for this kind of learning system, but are considered to be enough to develop the idea behind EducAR.

  The main functionalities of the learning application were developed from the instructional strategies defined on previous chapters. by recreating the proposed activities that the students could perform when using any these strategies. As some of the instructional strategies were involved in communication activities and others in interaction activities, in order to appropriately match the learning application with the instructional strategies, two models for the application were defined, a communication model and an interaction model. Each one of this models is in charge of different parts of the application, but can be easily integrated. By using this approach the development of the system was more structured and straightforward. The results obtained in the user tests showed that the use of the Augmented Learning and the set of instructional strategies, is suitable for teaching abstract concepts using an interactive and participative pedagogical approach.

- The use of the the real class metaphor during the synchronous content delivery process made easier for students the adaptation process to the new augmented reality technology, as there was not required any prior knowledge about the virtual class dynamics. In this metaphor all the interactions and communication strategies are designed to emulate a real class, but for syncrhonous and distanced learning. Thanks to the properties of augmented reality different metaphors could be used, but based on the proposed learning strategies and the variety of the public the real class metaphor is suitable for this learning system.

- The use of the UDP protocol showed to be a great election over the TCP protocol, by having the opportunity to easily establish a connection between participants at any time without the need of handshake between computers. Also the ability to design and codify each part of the message that each computers sends to the others was extremely useful. The internal structure and components of the message were the same for all participants, creating a common language which was shared by all participants.This lead to transparent exchange of data between all the participants, which can be used in future improvements of the system and for future applications. It can be concluded based on the general behavior of the system that the UDP protocol is suitable for synchronous augmented reality applications where the state of the augmented 3D model must be shared between computers.

- The Wiimote is a device that perfectly fits the interaction requirements that an Augmented Reality system similar to EducAR could have, In the hardware aspect this device has an adequate number of sensors, an infrared camera and a bluetooth connection that based on the experience acquired always worked very well. In the software aspect several contributed free software libraries can be found and different gestures can be created programmatically, and can be associated to different actions in an easy way. During the development process of EducAR one of the most straightforward parts was the construction of the functionalities related to the Wiimote, its connection, gestures and sensor control. Also the use of this kind of non conventional interaction devices in the context of e-Learning is recommended, as was showed in the reviews and comments made by the users in both phases, the use of a gaming device like the wiimote in an educational environment got the participants attention from the beginning.

- During the development phase, the use of contributed free software libraries along with the graphic and event oriented language Processing, provided very good tools for developing an Augmented Reality system for synchronous and asynchronous communication between multiple participants. Each library was used for one specific purpose and its integration was conducted step by step and functionality by functionality. This libraries integration process was not an easy task, some functionalities required the use of multiple libraries at the same time, so a deep analysis of the internal structure of this libraries in order to change their source code was required. For example the Jmol library which is in charge of drawing the molecules models required to be mixed with the Picking library which selects an specific part of the model, in this case any particular atom. Both functionalities where very related but it would not be possible to integrate them without the source code of the libraries freely provided.

Future Work

Although this Thesis has shown that the proposed system is able to deliver content in a suitable way and demonstrate that helped the studied group to acquire new knowledge in a appropriate way there are some aspects that can be addressed in future works:

- The interaction model was very well graded by the users, the use of mouse and keyboard to manipulate the 3D models show results near as good than the Wiimote however as this will be the most used way to interact with the system future research should therefore concentrate on improving the interaction model and the way to attach new actions to the mouse and keyboard in order to manipulate Augmented Reality 3D models in an appropriate way

- The communication model was tested in three forms: a synchronous class where the students share the same space with the teacher, a synchronous class where the teacher and students did not share the same space and a asynchronous individual learning mode. Future research can be concentrated on environments without a teacher where students can help each others. In order to do this the question and answers system should be checked and redesign, so the interaction without a centralized control to manage the questions can be possible

- The use of augmented reality to show the 3D models was successful, however the idea proposed by the students of showing the chemical reaction mechanism can be done using an augmented reality multimarker system. Future research can concentrate on design and develop the necessary changes in order to achieve this task

- EducAR learning application was adapted for teaching the organic chemistry subject however by using augmented reality EducAR has the potential to be applied on different subjects, as any kind of 2D or 3D model can be showed in the system. Future work can be the design of new 3D models that illustrate not only concepts but also phenomena and simulations

- EducAR used the pedagogical model known as Augmented Learning this is a new pedagogigal model proposed and developed by the MIT. Augmented Learning is specialized in Augmented Reality and learning games mixing the cognitive and the situative learning perspectives. Future research can be concentrated on finding new learning strategies that can be applied using this pedagogic model as those strategies are the ones that join the pedagogical model with the learning application

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