Bridging Digital and Physical Educational Games Using RFID/NFC Technologies

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Abstract

The physical educational games and the traditional psycho-pedagogical methodologies are deeply based on the manipulation of objects. The opportunity derived by some low-cost technologies could join the physical world with the digital tools creating Augmented Reality Environments based on the concepts of Internet of Things (IoT). This connection has all the capacities to enhance the traditional educational games played in the schools or at home with the digital tools in order to create more exiting learning activities and more appropriate for the new digital natives. In this field, the RFID/NFC technology seems to be a natural candidate due to its natural predisposition to be heavily connected to real objects and send the signal to the digital devices.

In this paper, we describe how the RFID/NFC technology could be used to connect digital and physical didactic materials in this hybrid approach. We present three different applications and prototypes: a) Block-Magic, it is an educational games based on well-known Logical Blocks material in the framework of an European project (I); b) Walden PECS Communicator (II) a platform based on Picture Exchange Communication System (PECS) a worldwide methodology to enhance communication skills in autistic persons; c) WandBot (III, IV), a learning environment that combines toy robots, RFID-technology and serious games for scientific dissemination in science centres.

Introduction

Traditional children games are mainly based on manipulation of physical objects (i.e. cards, building blocks, little toys, pencils, etc.). As well-explained by psychologists (Piaget, 1926; Bruner, 1990; Vygotsky, 1978; Papert, 1993;) they represent the “gyms” for children cognitive development. In these environments children use (smell, touch, taste, sight and hear) to explore holistically the physical world. Moreover, the utilization of concrete objects facilitates the interaction and cooperation between human beings (other children, parents, educators, etc.). The objects can be manipulated at the same time by many persons, this process is the basis of social and communicative skills acquisition. For these reasons, almost all psycho-pedagogical methodologies are based on didactic materials composed by concrete three-dimensional objects (Montessori, 1926, 1995; Montessori e Gutek, 2004). It is particularly true in the case of educational programs for children with disabilities. Recently, thanks of the commercial explosion of tablet-pc technology many of traditional educational games have a digital version that exploit the potentiality of touch screens as a surrogate of manipulation behaviours. The success of educational "apps" in very early ages demonstrates that just only pointing and moving digital objects is an attractive human-computer interface that definitely "capture" the children attention. On the other hand, there is an objective risk to expose our children to poor (digital) learning environments where they use only few sensory modalities in a solipsistic way.

Perhaps the Augmented Reality technologies and the recent Internet of Things (IOT) (Kranz, 2010) paradigm could be used to building up hybrid games where digital and physical sides could be harmonically used to enhance the traditional educational games. This kind of perspective could be used to support teachers, educators and parents to set learning/teaching environments that personalize the teaching/learning activities according to individual children needs inside the real world (De La Guìa et al., 2013)

1. RFID, the technologies for smart learning environments

The technology mainly used in this kind of smart learning environments is the RFID/NFC (Radio Frequency Identification / Near Field Communication).

RFID systems consists of an antenna and a transceiver, which is able to read the radio frequency and transfer the information to a device, and a small and low cost tag, which is an integrated circuit containing the RF circuitry and information to be transmitted.

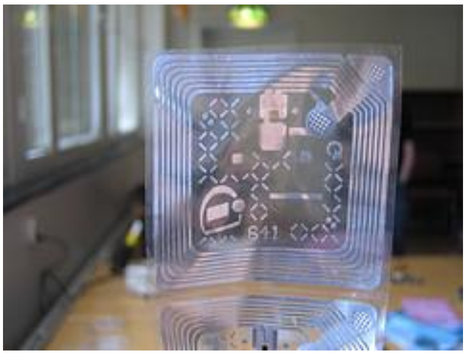

Figure 1: A typical RFID tag. The dimension of the square is in the centimeters order, with a minumum thickness

A significant advantage of RFID devices in comparison with the bar code or other technologies is easily recognition of tags, because the RFID device does not need to be positioned precisely relative to the scanner. These technologies are simple to use, so they are interesting for applications rather than on technical level. For example, they have been used as user interfaces able to recognize user manipulation on some objects on a surface, allowing their use in some application like board games where it is necessary to record user choices or actions sequence, with the aim to maintain an high interaction level.

The hybrid approach for smart learning environments could involve in parallel with the RFID/NFC decices also other types of minimally “invasive” tools capable of monitoring gestures and expressions. One example could be Kinect by Microsoft or the Leap Motion Controller, capable of recognising people's body movements.

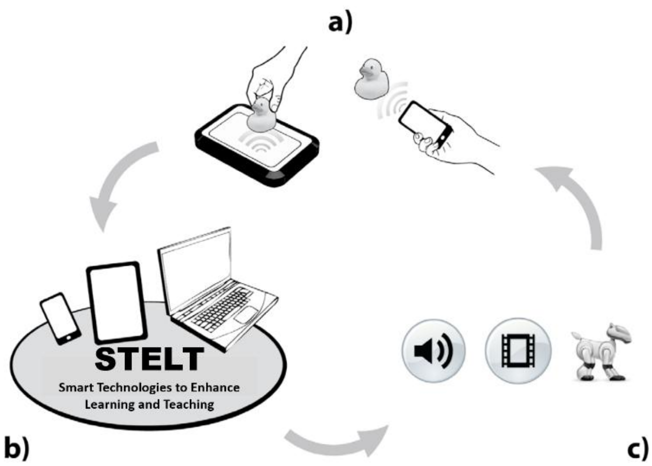

Figure 2: Description of a general augmented reality environment developed using STELT :
a) a user places an RFID sensor detector device and a previously «tagged» object in

contact; the detector can be inserted in a surface (desk) or an accessory handled by the user (smartphone, glove, rod); b) the signal is received by a calculation device (PC, Tablet-PC, Windows or Android smartphone) and is processed using the software developed with STELT ; c) feedback is given that may be an audio file, video file or the activation of hardware (e.g. a small robot).

The idea is to use every type of technology able to be "ecological" and low-cost, in order to extract a large amount of information without a direct conditioning of the pupils' activity. The data collected are useful for two main reasons: in order to design a learning profile of the child and in order to exploit that profile with benchmark psychological and pedagogic theories for a direct involvement through the increasing of the motivation of the learner in the smart environment.

In order to connect all these tools and for the implementation of Augmented Reality systems based on RFID, AIDVANCED s.r.l. in collaboration with the NAC Laboratory of University of Naples – Federico II, created a software platform called STELT. STELT combines communication protocols with the various hardware devices (readers and output devices), a Storyboarding environment for creating interaction scenarios of varying complexity, a Database for tracking the user's behavior and an Adapting Tutoring system that can analyze and interpret such behavior and provide relevant feedback into a single development environment. The STELT hardware and operational principles are shown in Figure 2.

2. Previous experiences and prototypes

In this section will be showed three real applications that aim to connect digital and physical educational games using the ICT technologies.

The three applications has three different target domains. The first prototype described is Block Magic that refers to the kindergarten and primary schools; the second application showed in this article is the Walden PECS Communicator (WPC) that aims to strength the interpersonal communication processes in people with serious cognitive-behavioural disabilities and finally we present WandBot an interactive environment, for the diffusion of science and communication in museums.

2.1 Block Magic, exploiting the traditional Logical blocks with RFID technologies

A European research programme in the framework of the LLP-Comenius programme, called Block Magic (www.blockmagic.eu) which ended in

November 2013, aimed to create a synthesis between physical manipulation and technology (Miglino et al., 2013). The objective of the project was to recover some traditional psycho-pedagogical, Montessori-inspired approaches, finalised at active learning/teaching for real inclusion of children, exploiting the opportunity of current technologies. Block Magic developed a functional prototypal system that enhanced the Logical Blocks Box (Dienes, 1971, 1972), a structured material widely used in kindergartens, primary schools, rehabilitation centres, baby-parks, children's hospitals and the home. The Block Magic research of developed an active desk/board able to recognise concrete blocks equipped with the RFID passive tag and to communicate with a PC or a tablet. Describing in more detail, the Block Magic teaching kit consisted, indeed, of a set of magic blocks (48 traditional Logical blocks), a magic board/tablet device and a specific software. (see figure 3) Each augmented magic block had an integrated/attached passive RFID sensor for wireless identification of each single block. A specially designed wireless RFID reader device, an active board, was used which could read the RFID of a block and transmit the result to the Block Magic software engine.

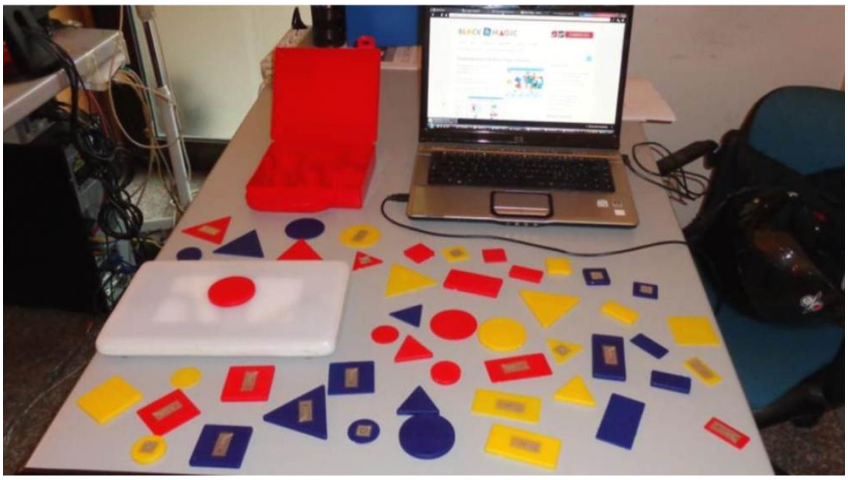

Figure 3: The Block Magic prototype that includes a tablet able to recognize each RFID tag and transmits the signal to the PC/tablet; a tablet equipped with a dedicated software and enhanced with Artificial Intelligence; 48 Logical Blocks tagged with RFID antennas

Dedicated software embedded in the engine exploited the Artificial Intelligence with a double task: on the one hand, to represents a trainer, able to seek the specific learning curve of each child and on the other to provide teacher or parents with a tracking system for evaluating the session played (see video at www.blockmagic.eu). The Adaptive Tutor System (an Artificial Intelligence applications that provides instruction that are tailored on individual learners needs) embedded in the engine that ensures autonomous interaction between the user and the system, receiving active support, corrective indications, feedback and positive reinforcement from the digital assistant on the outcome of the actions performed. Children maintain a high level of attention and surprise due to the aural and visual feedbacks sent by the system in correspondence with the actual learning path. The Block Magic project proposed, so, an hybrid version of Logical Blocks that allows an enhancement of traditional Logical blocks, equipping them with RFID tags. This configuration permits to a PC or a table, with Block Magic software installed on, to connect with Block Magic Table. The Magic Table has an hidden antenna that recognizes each block and sends a signal to the PC/tablets, and produces a feedback coherently with pupils learning path.

The Block Magic system aimed to stimulate and teach different skills such as logic, mathematics, languages, etc. therefore the described Block Magic enriched blocks together with the Magic Table are complemented with a software that includes a series of exercise that researchers, involved in Block Magic project, built on teachers feedback and on their previous experience in pedagogy.

The final software was developed through an iterative process: first children and teachers used the exercises and assessed them, then the results were collected together with feedbacks from direct observation and focus groups.

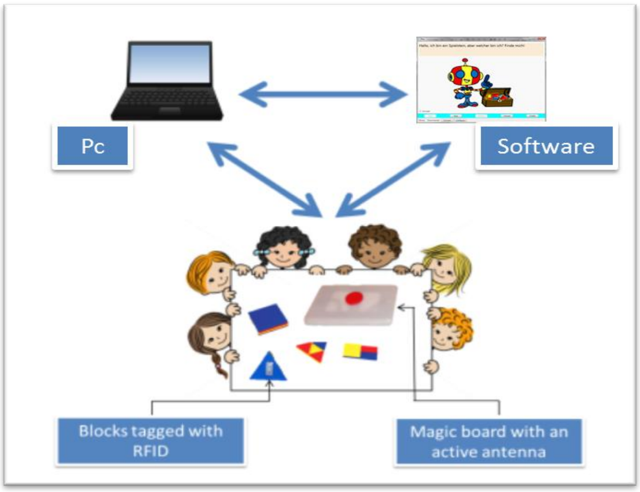

Figure 4: simplified schema of Block Magic. The children interact and use the Logical block tagged with RFID technologies and place it on a "Magic Board", an active antenna; the signal is transmitted to the PC/Tablet and the software engine proposes the appropriate exercises to the children based on the results previously collected in the session.

From the scientific point of view the research question of the project moves from the reflection that, if deprived of the digital component, the traditional learning activities require a constant interaction effort and supervision by an adult (teacher or parent) for a single child or small groups (2-3 children at a time). This produces a considerable increase in operating costs, which is one of the reasons why methods such as the Montessori one have not achieved widespread diffusion in public schools. Starting from this point of view, project researchers have tried to develop a system where the teacher or educator role is considerably reduced, becoming an *ex ante* planner and non-directive monitor and supervisor, rather than teaching practice ongoing following through and, in addition, tried to ensure that the artificial intelligence system was delegated to personalization of the learning activity for each children. Traditional applications used in education, indeed, are not individualized to learner needs, but are rather static and rule-based (IF Question X is answered correctly, proceed to question Y, otherwise go to question Z; and so on). The learner abilities are not taken into account. While these kinds of applications may be somewhat effective in helping learners, they do not provide the same kind of individualized attention that a student would receive from a human tutor. On the contrary, the Block Magic system allows each learning experience personalization: teachers can choose the exercises to be proposed to the child, focusing the attention on the skills the child needs to train more.

Trials involved 4 different schools, 257 students, 2 children with special needs and 10 teachers. Schools were located in 4 different countries (Italy, Germany, Spain and Greece). In detail the trial made in Italy was addressed for children with special needs, with little differences in the protocol and test contexts. Children involved were between 2.5 and 7 years old, attending the early years of primary school and kindergarten. To test Block Magic materials in educational context, the Block Magic project included two different scenarios: (1) Individual Game Scenario and (2) Social Game Scenario. In the first one, learners had to solve a task using logical, mathematical, creative, strategic and linguistic skills, whereas in the second one social skills, under group play guise, were necessary to find game solution.

Also teachers were involved with pupils: their role was to create and maintain an adequate environment for Block Magic sessions.

The trials were run in a specific setting: a dedicated rooms, different from the classroom where pupils attend traditional lessons. In these rooms large workplaces were prepared with the Block Magic kits, available for free game and manipulation.

The teachers, who had already experienced Block Magic platform, set the software choosing the correct level for children in the class. The trials had no pre-defined exercises for children who could skip exercises if they considered it problematic or boring.

A trial session typically started with introduction of Block Magic, Logical blocks and Magic Table device by the teacher, giving pupils the opportunity to play freely with them and use the materials in the way they preferred. The trial continuation was different according to the two scenarios introduced above. In the Individual scenario, the teacher acted as an external observer and supported a single pupil when he/she asked for help. This way, the child had to perform exercises autonomously. In the Social scenario groups composed by a minimum of 4 to a maximum of 6 learners were involved and the teacher had a more active role in the session, providing support, observing and/or creating obstacles.

The experimentation of Block Magic has demonstrated that these technologies can enhance psycho-pedagogical methodologies, extracting some aspects such as active children involvement, interaction with the environment, and the opportunity to promote innate social inclusion. These psycho-pedagogical methodologies potentialities on one side can balance out some limits of the modern tools described above, whereas, on the other side, these devices can generate surprise and appeal attention. In addition, these methodology/technology connections can guarantee learning/teaching personalisation offering at the same time, the strong scientific benefit of tracking each didactical session thus optimizing didactic paths. The experimental results were significant from the scientific point of view, demonstrating the accuracy of the approach but highlighting the need to face some technological challenges (Miglino et al., 2013).

Figure 5: A real session of Block Magic. The children play using the physical and manipulative actions and collect feedback by the digital tool

In the June 2014 it started an ambitious project named Inf@nzia Digi.Tales 3.6 funded by the Italian Ministery of Education and Research The project is aimed at children aged 3 to 6, thus including the first year of primary school, with the goal of renewing teaching and learning models in an educational context in this teaching segment. Inf@nzia Digi.Tales 3.6 represents an evolution of the results of Block Magic.

The project will explore the potentialities of the hybrid approach that intend to reuse traditional teaching experiences and materials daily used by teachers (as the Logical blocks, the teaching tiles, the cards, the images) exploring the well-known methods (Montessori, Munari) for an enhancement with the digital technologies.

2.2 Walden PECS Communicator WPC, reinforcing the communication for children with special needs

Several cognitive-behavioral related pathologies are associated with pervading disorder of oral language use. Augmentative and Alternative Communication (AAC) (Beukelman e Mirenda, 2005) systems have helped people with such disorders to communicate with others for several years now. There are two types of technology in this context: Speech-Generating Devices (SGDs) (Van der Meer e Rispoli, 2005) and Picture Exchange Communication System (PECS) (Charlop-Christy et al., 2002) The former are devices for vocal production and are also known as Voice-output Communication Aids (VOCAs), which can be programmed to reproduce audio-recorded messages or which can use speech synthesis systems. There are simple versions of this type of assistive technology, based on microswitches and complex ones that can generate an infinite number of messages using speech synthesis technology. Picture Exchange Communication System (PECS) teaches a functional type of communication using the exchange of images printed on paper that show objects (toys, food, daily living items etc); people or actions (eating, drinking, going out...).

Recently, thanks to the possibility of using tablet touchscreens, it has become possible to combine the PECS method with that of SGDs. These applications (APPS) allow a patient to choose the images that attract his interests (or needs) on the tablet screen, and then software then produces an audio file - a sentence - that the educator or parent can hear. PECS, SGDs and a combination of both are interpersonal communication support methods that are widely used worldwide. Their widespread use has also brought to the fore some critical points that are listed below:

in order to be listened to by the communication partner, a message generated by the SGDs must be heard at a sufficiently high volume; the resulting acoustic pollution effect limits its use in inclusive environments (school class, work group etc);

the communication partner must be close, however, (for example in the same room) to be able to hear the voice message;

The most simple systems (i.e. the ones based on microswitches) are basically applications that are difficult to modify other than by experts. In other words, adding new pictures and new sentences is an operation that required an IT programmer's skills.

This reduces flexibility and personalization that are extremely necessary for people with serious disabilities;

the recent technologies that integrate PECS and SDGs and use tablet touchscreens overcome some of these limitations, but force people with serious disabilities to have to face some abilities (handling and understanding of digital environments) that are difficult to learn.

The joint between Walden Technology, Aidvanced and Laboratory for the Study of Natural and Artificial Cognitive Systems at the Federico II University in Naples has created a first prototype, the Walden PECS Communicator (WPC), which aims to solve the limitations that are stated above. The WPC allows a person with disabilities and serious verbal language problems to use the traditional PECS cards and to send a visual and text message (audio and/or written) to a caregiver (educator, parent, rehabilitation worker, etc.) who may be some distance from the person with the disability (for example, in another room). The WPC also has an author system that easily allows the collection of pictures and associated (audio and visual) messages to be increased. Generally speaking, the WPC works according to the following steps: a) the disabled person places the «tagged» PECS cards with RFID sensors in contact with a reader (RFID reader with Bluetooth connection or smartphone with NFC sensor); b) the signal is picked up and sent to the caregiver's smartphone; c) the software residing on the smartphone recognizes the tag and issues a visual message (digital reproduction of the PECS image) and a text message (written and/or spoken) that the caregiver can easily understand. An initial WPC prototype is currently being evaluated by Professor Giulio Lancioni's research team at the University of Bari. The first data show that the subjects allowed to choose between using the traditional PECS and the I-PECS (the ones supported by WPC) prefer the latter to the former. Also, the WPC seems to stimulate communication requests. Indeed, the number of requests carried via WPC is significantly higher than the ones made using traditional PECS. Parents and educators have expressed their liking of the WPC system compared to traditional PECS and SGD systems or a combination of both.

In the study of communicative and rehabilitative methodologies is customary to conduct experiments on single subject. Generally we proceed with a pilot study, mainly to the validation of the instrument. The pilot study conducted with WPC has as main purpose to strengthen technology described above, and check if a person with multiple disabilities prefer to use the traditional communication tools (PECS) or WPC. The pilot study was conducted on a 7 year old girl suffering of multiple disabilities and mainly affected dismorphogenic syndrome with partial trisomy (ICD10 RGN 090). The experimental subject is also affected by severe mental retardation, impaired hearing and vision, total dependence from the adults or care givers, and motor difficulties in the global and fine movements, associated with a strong inability of attention. The experiment is based on specific task, the subject have to perform a request (activity, food, feedback) by the use of pictograms (PECS) , choosing among a set of items consisting of 15 photographs of 6x8cm format, illustrating objects/activities for which the child feel greater preference.

The girl is already using the traditional PECS system from a year before the experimental session, learned during a rehabilitation program and with which she is able to make autonomous requests, discriminating objects and activities. The requests are always made in proximity of the care giver and with a reduced distance due to motor difficulty. The experimental setting consists in a private house, the girl had the set of images and the WPC system (RFID reader and mobile phone and images with RFID/NFC tags). Before the use of WPC, the researcher performed a pre-training program, in other words a phase of familiarization with the technology; it consisted of 16 sessions, lasting 10 minutes each. The pre-training ends when the subject was able to use the tool in total autonomy. The intervention sessions conducted during the pilot study were 40 with a duration of 5 minutes for each session and with an interval of 10 minutes between one and another, for a total of 8 daily sessions. The measure under consideration in the pilot study was the subject's preference between the use of the traditional PECS system and WPC, the measurement was carried out using the methodology of preference-check, so at the session number 3 of each day, the subject had to choose if she wanted to use the traditional system or WPC.

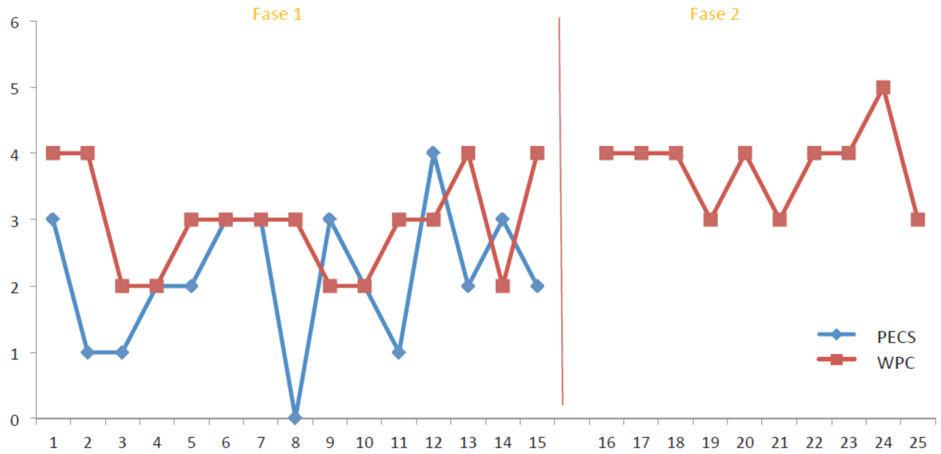

Figure 6: The graph shows the performance of the subject involved in the pilot study. On the X axis is present the number of sessions, the Y-axis the number of requests made over the tool to use.

The exploratory study has confirmed the selection of the WPC by the subject and has demonstrated the strength of the technology. The graph shows the number of preferences towards PECS system (blue line) and WPC (red line).

2.3 WandBot, stimulating the scientific dissemination with an interactive tool

Installations provided in Museums, Science Centers and mass events - such as topic-related festivals - encourage active participation from visitors through the creation of highly interactive environments. In such a context, the Laboratory of Natural and Artificial Cognitive Lab (NAC) at the Federico II University in Naples has developed a setting named WandBot that creates interactive exhibits in a wide area of subjects, continuing the experience of the research laboratory (Miglino et al., 2009; Rega, 2009, 2012) WandBot invites a group of visitors to take part in a treasure hunt within any given large space, which may be the entire building. The answers to the various questions in the game stimulate a small mobile robot that travels along a stretch of the route and takes them to the finish. Each participant has wand, the questions appear on a large screen and challenge the "hunters" to find the items and touch it using the wand. The faster the group of visitors answers treasure hunt clues, the quicker the robot reaches the finish.

These items and places are tagged with RFID sensors and also have portable readers (rods) and wand is able to recognize each of them. The readers communicate with a computer containing a software platform connected via Bluetooth, which activates the screen showing the questions and the mobile robot built using LEG O-NXT constructions kits.

There can be several installations of WandBot in the same museum space, therefore the various teams can compete and see who manages to take their own robot to the finish line faster. Installation developed using WandBot concepts were exhibited at Naples' "Science Center" and the Genoa Festival of Science (2011) (Rega, 2011). It proved to be highly successful with the public, proved by the sell-out of booking for game sessions that were organized. WandBot prototypes were found to be enjoyed especially by children in the 5.12 year age group, rather than by older children. Now we describe a scenario used to show Wandbot in science center with the purpose of developing an interactive game where the learning content was based on the acquisition of new English words. This prototype integrates the Lego NXT robot in educational games is the result of previous research experiences that were intended to use edutainment robotics system to link digital and real world (Miglino et al., 2007).The exhibit was also planned for giving to visitors of science center a chance to experience an interactive game based on augmented reality systems. The game consist in a race between robots where the winner is determined by the actions that the player performs in the surrounding space. Below we describe in detail the scene and game play. The setting of the game is composed of 3 lane of 2.5 m long and 40 cm wide. In each lane there is a Lego NXT robot and, at the head of each lane, is placed a computer with a big screen (24 inch). There are scattered objects of various nature and shape all around. A camera shooting the entire scene from above and display it on a large screen to allow spectators to follow the race (Figure 7).

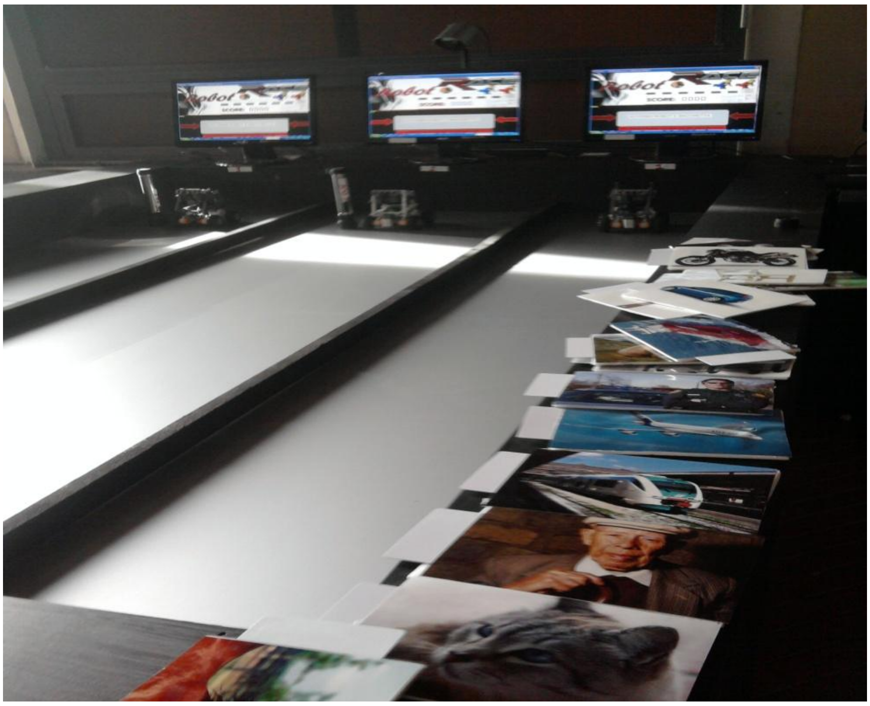

Figure 7: This image shows an example of Wandbot as it is installed in the science center.

All players are located in front of computer monitor and have a magic wand (an RFID reader to touch objects). The game start when on the screen appear an English word corresponding to one of many scattered objects. Each player must understand the showed written word on the screen and have to run around looking for the corresponding object. Once the player find the object, must touch it with the interactive wand (RFID reader), and have to bring it. If the object corresponds to the word appeared on the screen, the robot runs forward and stops after a few seconds, so the computer shows a new words, and the player must again look for the corresponding object. The player who finds most items and so reach the finish line first with his robot, win the game. The game is designed for children who attend primary school because, during these years, they start to study foreign languages and to enrich their own vocabulary of English words. We also conducted a pilot study in a school in the city of Naples. The study involved two classes (A and B) of first grade of elementary school, for a total of 52 students, 26 students for each class. The aim of this pilot study was to test the students' interest towards these new forms of learning and test whether children learn more English words in the traditional front lecture or through the game. The first step of the pilot study consist in the administering a comprehension test of English words containing 20 items. The test was submitted to both classes (A and B). Later were conducted 5 sessions to teach new foreign words. The class A has conducted five hours of lecture with the teacher, she showed the pictures, explain the word in English and ask for repeating it to all pupils. The class B, however, has not led standard lectures, but 5 hours of playing with Wandbot system.. Later both class were again administered the test to check the knowledge of new English words. The results showed no differences, both classes had learned almost the same number of new words. The main highlighted differences consisted in the perception of the learning process. During the final focus group we could note how the pupils of A class perceived the lesson very boring and did not have socialized, while pupils in the B class perceived the learning experience much more fun and socializing. Of course, we have to consider that the data collected cannot be generalized, but they represent only an observation on a small group of subject. What, however, can be argued, is the increased of socialization skills during the use of Wandbot.

3. Conclusions

Some technologies, e.g. augmented reality, RFID/NFC sensors, the Internet of Things, are natural candidates to represent the hybrid approach, which unites the manipulative approach and touchscreen technologies, connecting these two worlds in order to be hidden to the children. The main idea is that the children plays and learns with traditional games but with enhancement given by the ICT technologies. Previous projects have demonstrated that these technologies could enhance psycho-pedagogical methodologies, extracting some aspects such as the active involvement of children, the capacity for integration and interaction with the environment, and the opportunity to promote innate social inclusion. These potentialities are in accordance with some limits of the modern tools described above, without the loss of surprise and attention engendered by these devices. In addition, these connections can guarantee personalisation of learning/teaching as well as a tracking of the sessions and an optimisation of each didactic path.

The main goal of this hybrid approach is to create a games environment for active learning (a sort of environment/class 2.0 that could be also brought out of school) which, along with fostering the acquisition of fundamental cognitive skills and empowering effective learning processes facilitated by the central role of the manipulative act, aims to promote the importance of collaborative behaviours as a motor of social inclusion. Thus, the prospective of this kind of applications is focalized on children with special needs – such as cognitive and sensory disabilities, and children belonging to linguistic minorities or disadvantaged social groups – through the active involvement of the child, by using low-cost ICT technologies common in everyday device such as smartphones. The games environment would enhance structured materials with some hidden and ecological technologies, in order to enable communication between the tool and the PC/tablet.

This “class 2.0” could be reinforced by Artificial intelligence, using Adaptive Tutor Systems that are able to enrich the system, allowing personalised and advanced tutoring for each educational path.

It gives the chance to personalize the didactic paths, through the individuation of specific goals for each pupil, and tracking every child's learning achievement, which, in turn, offers feedbacks that can be used for the redefinition in itinere of the didactic path. The customization is another important strength point of this approach allowing the teacher able to create and adapt own exercises with ad hoc authoring systems designed for every type of PC users. The authoring system is particularly useful to adapt the didactic practices to the educational requirements of children with special needs (linguistic minorities, children belonging to economic disadvantaged social groups, pupils facing learning difficulties and with disabilities, etc.). The prototypes described in this paper are the result of a research that our team conducts for several years trying to pursue investigations on new learning systems including: computer simulations, robot and multi-user games (Miglino et al., 2007).

The next steps for bridging digital and physical educational games are the improvement of the AdaptiveTutoring Systems and the customizable Authoring Tools.

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