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IMPROVING LEARNING WITH AUGMENTED REALITY: A DIDACTIC RE-MEDIATION MODEL FROM INF@NZIA DIGITALES 3.6

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The diffusion of information and communication technologies, in the last decades, appears to be a great opportunity in teaching and learning processes, not necessarily due to different learning supports.
Augmented reality (AR), in particular, appears one of the plausible solutions for transforming learning methods, supporting students to have educational experiences able to involve all the senses and increasing motivation and engagement levels.
This paper provides an approach for using augmented reality in human learning in the context of a novel didactic re-mediation model. Moreover, this paper includes also the description of an application (Mobile App) developed as one of the results of Inf@nzia Digitales 3.6 project.
The described learning experiences are designed for children from three to six years. The main topic of the experiences is represented by the discovery of geometric shapes in a smart city, and their understanding as road signs.

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1 Introduction: the context and the target

In recent years, it has been recognized an increasing interest for digital technologies that profoundly transform educational processes as we traditionally know them. In Italy, some of the objectives by the new National Digital School Plan (Ministerial Decree 851/2015) consist in the construction of an active and interactive learning system where spaces, materials and technologies are adapted to the users, in order to create educational settings increased by technology (Miur, 2015).

Technology Enhanced Learning (TEL) researches are focused on emergent technologies creating a meaningful learning for students. In particular, Augmented Reality (AR) seems to have a high potential for pedagogical applications. AR is a new media supported by specific hardware and software technologies which overlays virtual objects (augmented components) into the real world (Azuma et al., 2001). Currently, there are three main types of AR devices: i) Head-mounted displays and Wearables, ii) Mobile handheld devices, and iii) Pinch Gloves. The devices belonging to the second category, i.e., mobile devices, are prevalent and can be easily put into learning settings.

Meta-review and cross-media analysis demonstrate many advantages that AR offers when it is adopted in educational settings, also comparing AR to non-AR systems for learning: in fact, AR systems seems to increase content understanding, students' motivations, physical task performance, spatial abilities and collaboration among learners (Radu, 2014; Akçayır e Akçayır, 2017). In particular, the key elements that guarantee a greater learning experience are multiple and simultaneous content representations, according to the cognitive theory of multimedia learning (Mayer e Moreno, 2003; Mayer, 2005) and the physical involvement in the activities (Vincenzi et al., 2003; Shelton e Hedley, 2004).

Most of the studies on the use of AR in educational context are applied in higher and primary education settings: the state of the current AR application in Early Childhood Education is still in its infancy (Bacca et al., 2014). However, in recent years some pilot studies have proved the potential of using AR in different domains of learning in the age segment from three to six years (Huang, Li e Fong, 2016; Yilmaz, 2016).

Starting from these premises, the Inf@nzia Digitales 3.6 Project[1] tried to integrate the new possibilities offered by ICT with the main pedagogical theories for children from three to six years, in order to enhance the fruition of cultural assets or points of interest in smart cities. Cities, in fact, offer a poten-

[1] Inf@nziaDigiTales3.6 is a research and development project co-funded by the Italian Ministry of University and Research under the PON Research and competitiveness 2007-2013: Smart Cities for Social Inclusion. A quite complete description of the project can be found in Miranda, Marzano & Lytras, 2017.

tially infinite number of real-life situations (e.g., visiting museums) that can be exploited to build situated learning experiences.

2 The didactic re-mediation model from Inf@nzia DigiTales 3.6

2.1 Cultural re-mediation and digital storytelling

Child development, especially in the range from three to six years, is characterized by the progressive appropriation and transformation of the cultural artifacts offered by the environment in which they live (Vygotsky, 1962; Bruner, 1986). In these years, is not a coincidence that children perfect language acquisition and their mental representations, or abstractions of real objects that continue to exist, in their mind, even in the absence of it (Piaget, 1964). Indeed, they create imaginary situations to go beyond the limits of their concrete and real possibilities of action, also using symbolic play (Bretherton, 1984).

Even ICTs provide the ability to generate other representations of the world, implementing a real transformative action on reality. This is the exemplary case of AR that supplements reality with virtual objects superimposed on the real world. Considering the continuum that leads from the real world to the virtual one, AR is the most proximal to what happens in reality, connoting the concrete learning experience and interactivity (Milgram e Kishino, 1994). In fact, while Virtual Reality (VR) tends to replace the real world with a completely different and ad hoc one, AR enriches it because real environment is augmented by means of virtual objects. This increases the user's perception and interaction with the environment by providing visual information that the user could not directly detect by means of her/his senses.

From these assumptions, the didactic re-mediation model from Inf@zia Digitales 3.6 is based on the integration of natural and media languages, and starts from the principles of re-mediation theory (Bolter e Grusin, 1996; Bolter, Grusin & Grusin, 2000). Bolter and Grusin define re-mediation as the representation of a media in another media, and affirm that it is founded on two conflicting and antithetical approaches: immediacy and hypermediacy. In the logic of immediacy, the purpose of the medium is to disappear, removing the mediated nature of experience (e.g. immersive technologies). Instead, in the hypermediacy logic, the mediated nature of experiences is clearly visible (e.g. hypertexts).

Starting from the works of Deuze (2006) and Manovich (2001) can be defined a new remediation mode, named *ad-mediation* (Ciasullo et al., 2016), which is not focused exclusively on the contraposition between old and new media (Immediacy vs Hypermediacy) but considers the knowledge acquisition through continuity or through differences related to prior knowledge (Similarity vs Dissimilarity).

The combined use of AR and mobile devices fosters the natural integration of natural and media languages in the context of a sort of game experience, guided by narrative plots, in which children are able to move on the different axes of knowledge mediated by technology, including those related to Symbolism/Realism (fig.1).

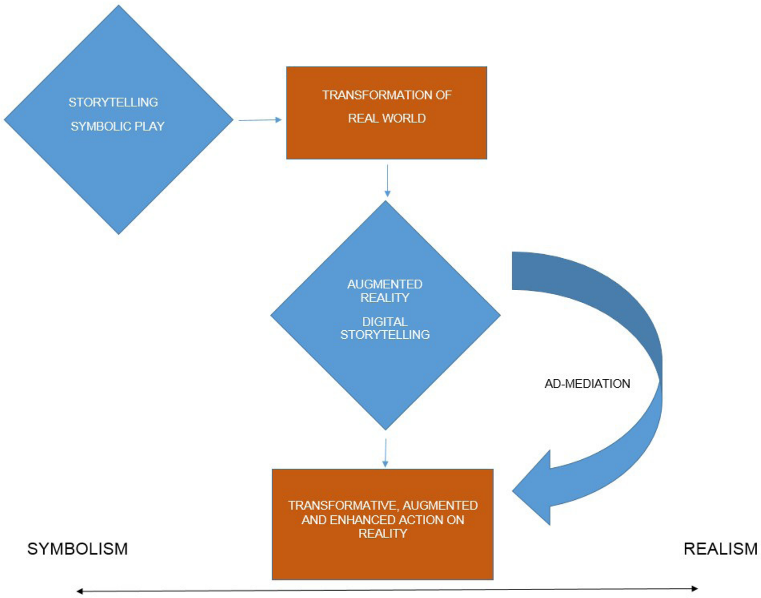

Fig.1 - Cultural ad-mediation in Inf@nzia Digitales 3.6

Therefore, learning mediated by technologies can be one of the main tool for exploring *possible worlds* through the action of a narrative thought (Bruner, 1990) that assembles and gives meaning to children's cognitive experiences. The result is the meaningfulness, already in this age group, of activities that integrate narrative thinking with new technologies, through the use of digital storytelling (Lambert, 2013; Robin, 2008), preferably interactive (Gaeta et al., 2015) to allow them to manipulate cultural objects (Capuano et al., 2016).

An additional enabling technology to support gathering and processing of data in the (smart) city is represented by ontologies (Miranda, Orciuoli e Sampson, 2016). Lastly, it could be also possible to enrich data and content coming from the city by using social media content (Cuzzocrea et al., 2016).

2.2 Meaningful learning and metacognition

Further inspiration for the model comes from Ausubel's contributions to meaningful learning (1968). According with Ausubel, learning in a meaningful way indicates, for students, processing information actively. Learning becomes meaningful only if new content can be integrated with that controlled in previous cognitive schemas. This is possible when prior knowledge is ascertained and recalled during learning processes, causing an extension of students' cognitive structures. This mechanism can be compared to assimilation and accommodation processes described by Piaget (1947) during the intellectual child development, where intelligence is the result of a state of balance between the organism and the environment.

In addition, the *Italian National Indications for the Curriculum* (Miur, 2012) in the description of school learning environment, emphasizes the importance of enhancing the experience and knowledge of students. In fact, a child involved in a learning process already brings with her/him a rich wealth of experience and knowledge acquired outside the school. Such wealth should be appropriately recalled, explored and problematized by teaching processes in order to make sense of what has been learned.

This approach presupposes a continuous reflexivity, intended as a solicitation to the metacognitive processes of learners and focused on developing her/his self-awareness related to the learning experience (Flavell, 1979). Recognizing encounterd difficulties and strategies adopted to overcome them, acknowledging mistakes, but also understanding the reasons of failures and knowing their own strengths are all necessary capabilities to make children aware of their learning styles and able to develop autonomy in the study. Learners should be supported in understanding their tasks and goals, recognizing difficulties and estimating their abilities, learning to reflect on their own results, assessing progress, identifying limits and challenges to be faced, being aware of the results of their actions and drawing considerations.

2.3 Intelligent tutoring

Another aspect of the proposed model is represented by socio-constructivist pedagogical approach, and concerns the relevance of the social dimension of human learning. In this approach, forms of interaction and collaboration can range from mutual aid to cooperative learning to forms of tutoring and cognitive apprenticeship. In kindergarten and primary school, a significant role in supporting learning is assumed by working in pairs, through the helps provided by a more experienced peer or by an adult figure, according to the Vygotsky (1978) principle of proximal development zone (ZPD).

The teacher, or a more experienced peer, plays a scaffolding function (Wood et al., 1976) providing support and guidance that are necessary to resolve problematic situations and/or tasks that the child is not yet able to perform alone. Of course, to be functional, these tasks should not be too much above the cognitive abilities of the student.

While human tutor's behavior is highly adaptive because he estimates the ZPD and the current state (cognitive and affective) of the learner and selects the task to propose, technology-based instruction needs artificial intelligence systems providing individual learners with hints, examples, explanations and problem solutions. To solve these problems researchers designed and developed software that can simulate the actions of a human tutor, monitoring the interaction of the learner in educational games, such Intelligent Tutoring System (ITS) and Adaptive Educational System (AES). The use of ZPD in ITS has been investigated in Fenza e Orciuoli 2016; Fenza, Orciuoli & Sampson 2017; Capuano et al., 2008; Adorni et al., 2010.

To this purpose, the intelligent tutoring approach, developed in the context of Inf@nzia Digitales 3.6, aims to automatically adapt tutoring actions to learning needs and progresses of children, providing the benefits of one-to-one instruction. It can be articulated in these operational phases:

1. *Modelling* (Bandura,1969), or the initial execution of task by the expert, represented by a character guide;
2. *Scaffolding*. The character guide assists the child by providing suggestions and adapts feedback related to the task performance, ensuring him support to exercise his competence. This support, however, will be progressively reduced to allow the latter to develop operational autonomy (fading).
3. *Reflection*. When there are several difficulties and mistakes in proceeding, child's performance is compared to that of the expert through a guided reflection;
4. *Restructuring and cognitive expansion* by the integration of old and new interdisciplinary learning contents.

3 Application: Bigfoot the Pedestrian

The AR application is an educational game that refers to interdisciplinary learning activities situated in a (smart) city. Led by an intelligent tutor, called *Bigfoot the pedestrian* (fig.2), children can recognize the meaning of different road signs and their geometric shapes, to group and sort objects and materials according to different criteria.

Bigfoot is a 3D virtual child with a lively, cheerful and friendly character capable of arousing empathy, curiosity and interest, modelled by using LightWave

3D software[2]. He guides and supports children through the phases analyzed in 2.3, in order to the increase autonomy and self-esteem, trust, responsibility and safety. The educational objectives of the game are: i) recognizing road signs in the real world, also by analogy with known geometrical shapes; ii) stimulating children with a 3D character able to move and talk; iii) allowing touch interaction and voice commands (Speech Recognition); iv) presenting a user-friendly layout to reduce comprehension and interaction efforts. In this way, the completed experience allows the growth of new knowledge through the restructuring and rearrangement of the previous one. Below, it is possible to see a summary table (tab.1) that links the phases of the game scenario with their description.

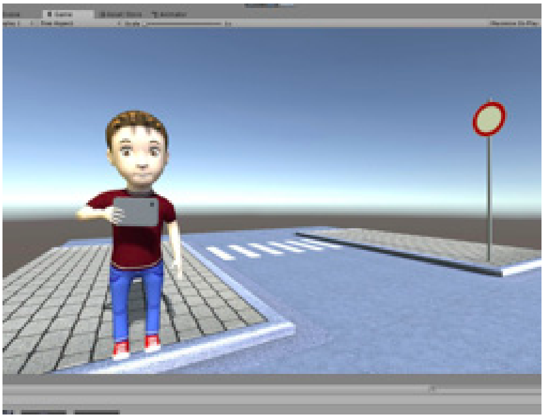

Fig. 2 - Bigfoot the pedestrian

The application has been developed by using Unity 3D and the AR engine Vuforia[3] that recognizes and tracks planar images targets, simple and complex 3D objects and models targets in real-time. In this specific case, if a tablet (or a smartphone) focuses on, through their camera, a road sign, the proposed application recognizes and tracks the sign in real-time and an educational game is generated and rendered automatically and contextually. Therefore, when the child starts the game and moves in the city, Bigfoot appears on the device screen, greets the user, introduces himself and invites the child to play the game and find out the meaning of the road signs. The game is presented by visualizing Bigfoot who asks a question about the signal and the corresponding shape. Now, the child can use the UI (User Interface) buttons for making her/his selection, typically, in a multiple-choice test (fig. 3).

[2] https://www.newtek.com/lightwave/2019/

[3] https://engine.vuforia.com/engine

Table 1
PHASES OF SCENARIO

Phase	Description	Main characteristics
Introduction	Tutor's storytelling Introduction to the game	Digital storytelling
Presentation	Recall, by the tutor, of the cultural objects present in the city	Reference to the cognitive matrix of children
Expert performance	Explanation, by the tutor, of the game mechanisms	Observational learning (modelling)
Child performance	Learning task request	Verification of prerequisites
Consolidation of learning contents	Interactive game Tutor suggestions and intervention in case of correct and / or incorrect answers from the child.	Scaffolding Increase of ZSP Adapted feedback Positive reinforcement Symbolism/Realism Active research of contents present in the environment
Expansion and transfer	Presentation of additional disciplinary and interdisciplinary contents	Transfer of learning

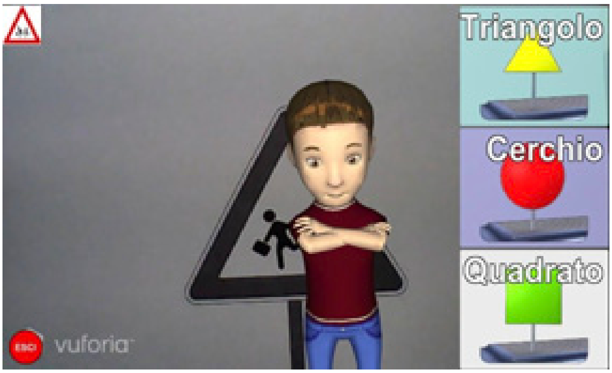

Fig.3 - Example of a multiple choice

4 Exploratory research: first results

An exploratory research has been conducted from May to June 2018, with the aim of detecting first results about the acceptability of a first trial of the developed application deployed at an Android Tablet, the degree of satisfaction and involvement of the learners, as well as the achievement of the learning objectives associated with the game activity.

This study involved 107 children (six years old) from first classes of two Educational Institutions in the province of Salerno (Italy), through a pre-experimental design with one-group and post-test only (Cohen et al, 2002).

The phases of the experimentation were the following:

- Preliminary interviews with the executives and teachers of the involved Institutions;
- Verification of the Three-year Training Offer Plan (PTOF) of the involved Institutions;
- Preparation of the learning environment and the materials for the experimental activity;
- Game activity carried out in the laboratory in the presence of the experimenter, the observer and, where possible, of the class teacher (fig.4). A structured children's observation grid has been compiled during the game by experimenters, in order to verify the acceptability of the tool (application) and the engagement among students;
- Execution of a short structured questionnaire (six items), by the students, on the degree of satisfaction and involvement during the game. Some of these items are adapted from the System Usability Scale (SUS) (Brooke, 1996). The questionnaire has also collected additional data such like children gender, age and their use of tablet at home.
- Execution of a final learning task by the students. In this task, children individually answered five questions concerning the meaning of some road signs, one of which related to the recognition of the geometric shape present in one of the signals.

Fig.4 - Children involved in the execution of the game

The planned activities had, for each participating class, the duration of a school day. In fact, children have been divided into small groups in order to increase their engagement.

Analysing the collected data of the short structured questionnaire, it is possible to affirm that there is a certain gender equality among the participants (50.4% male; 48.6% female). Moreover, the majority of the trial participants own a tablet (81.3%) and the 66.3% of them admitted to use it frequently. This means that the use of tablets is widespread among children and is largely a great attraction even in the school context, especially if associated with a strong interactivity, provided by specific applications, such as that provided by AR.

With respect of the level of engagement expressed during the game, almost all of the children provided positive opinions (94.3%), confirming the pleasantness of the game experience. In fact, the large majority of children (92.5%) affirm they have pleasantly acquired the proposed contents, and a majority of them (89.7%) state that they would like to have this *special* application in their school daily. The results of the observation and the interviews with the teachers also revealed that children with special educational needs had no difficulties to focus their attention during the learning experience, if compared to a traditional learning activity (e.g., frontal lesson of a teacher), favoring the inclusion of children in the 89% of cases.

The analysis of the answers coming from the final learning task is generally positive, despite we do not have greater certainty about the consequentiality between the introduction of game and the learning outcomes (given the lack of an initial pre-test and a control group). Around 51.4% of children answered correctly to at least four (of the five) questions, while those who made no mistakes were about the 34.5%. Furthermore, no pupil scored less than the two correct answers (of the five) (fig.5).

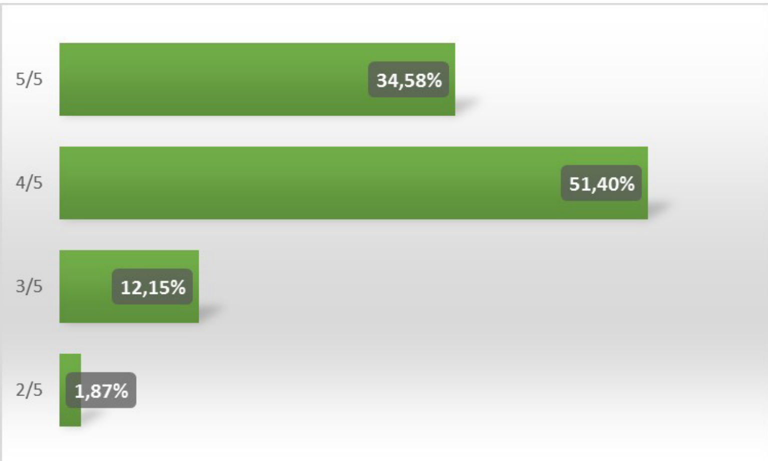

Fig.5 - Percentage of correct answers.

In addition, the application is also been presented and used, besides this formal experimentation, at Giffoni Film Festival 2018[4], in the context of a Showcase on Innovation dedicated to new technologies for human learning. At Giffoni, children used smart glasses to live an even more engaging game experience (fig.6). Thus a porting of the application onto Microsoft HoloLens has been realized to accomplish the objectives of the aforementioned Showcase.

Fig.6 - The Giffoni Film Festival experience.

Conclusion and future works

The AR-based interactive situated learning experience allows children to enjoy a learning moment involving different senses. Sense and movement, in fact, are fundamental for the development of the child and provide her/him with fruitful ways of exploring the environment and constructing abstract thought (Montessori, 1948). For these reasons, it is possible to envision the use, in classroom, of multisensory applications that put together digital tools and physical materials, thus fostering motivation and engagement of students, also with special educational needs (Miglino et al. 2014; Ponticorvo et al., 2018).

Of course, it is needed to re-think and re-model the traditional learning spaces in order to adapt them for the use of such new tools based, for instance, on AR. An example of is the one realized during the aforementioned experimental activity. Such laboratory has been constructed in order to provide students with the capability of exploring the surrounding learning environment, full of stimuli, both independently and under the guidance of the adult (e.g., tutor, teacher, etc.).

The role of the intelligent tutor has been represented, in the game, by a

[4] Giffoni Film Festival is a film festival for children and young people that takes place every year, in the month of July, for about ten days, in the city of Giffoni Valle Piana (Salerno, Italy). https://www.giffonifilmfestival.it/

character guide. The presence of a virtual tutor, however, does not exclude the involvement of peers and adults in the learning process. During the experimental activities, in fact, the support action did not take place only between child and virtual tutor, but also between different children and between the child and one or more adults, to emphasize the situated nature of learning. Even in this case, new technologies augment the real world but do not replace it.

Definitely, the proposed didactic re-mediation model is based on the idea that the numerous information sources (generated by heterogeneous points of interest) of the (smart) city can be used to build situated learning experiences. Such experiences can be implemented, in the future, through both integration and alignment of multiple educational scenarios.

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