Game@School: Teaching STEM through Mobile Apps and Role-based Games

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***Abstract* — Dealing with digital native students requires new methodologies of teaching. In this work, we describe an approach and a conceptual architecture of a supporting teaching tool that takes into account two main objectives in new teaching trends: Virtual Learning Environments (VLEs) and Intelligent Pedagogical Agents (IPAs). The main idea is a VLE that in turn is a role playing game. The game structure follows a quest-based game that is deliberately designed as a system of problem-solving activities aimed at achieving objectives, to be successfully addressed in order to progress and eventually win. The emotional behavior of the IPAs has been built by conducting a study on emotions with high school students. Stemming from the study results, it has been built an Android application that uses the IPA as a standalone application to prove the efficacy of the IPA itself.**

***Index Terms* — Intelligent Pedagogical Agent (IPA), Role-playing game, Virtual Learning Environment (VLE)**

I. Introduction

Over the last ten years, the way in which education and training is delivered has changed considerably with the advent of new technologies. Thus, technology should be a prominent part of the learning process and should be intended as a support for teachers and learners. One new technology that holds considerable promise for helping to engage learners is Games-Based Learning (GBL) [1]. The term game is quite ambiguous, that means that researchers, game designers, parents, students, teachers, etc. have a different concept of games. In this work, we intend games as inquiry based laboratories in which participants are able to imagine, engage with, and reflect upon their experiences. Games are intended as scenarios, following [2], which directly refer to the dynamic, future-oriented models for possible actions that are embedded in game designs.

Gaming and schooling have developed into two distinct “knowledge traditions” that often rely on opposing validity criteria for determining what counts and what does not count as relevant knowledge. To avoid that dichotomy, GBL should integrate different aspects that are related to the knowledge itself, to pedagogical aspects, to scenario-based and every day practice [2]. We matured the idea to develop a *serious game* that integrates the most up-to-date technologies in new teaching trends [3]:

- Virtual Learning Environments (VLEs);
- Intelligent Pedagogical Agents (IPAs).

II. Game@School description

A. Overall design

Prensky [4] coined the term digital native more than ten years ago: “Our students today are all native speakers of the digital language of computers, video games and the Internet". We are persuaded that this term still describes a generation of students that grown up tight to technology and that somehow suffer from the lack of technology in classroom lessons.

The main idea of our research is a VLE [5] that in turn is a role playing game. The role playing game is a social game in which each student becomes a player with her abilities and her tasks. In order to succeed, all the players should work to achieve a common objective/goal. The storyboard is designed in a way that there is an evolution in the role playing game and a progress in the level of learning as well.

The idea of helping students in the process of learning in a different way with respect to the classical approach finds support in many psychological studies and previous work, in particular we refer to Howard Gardner theory (1983): “We might think of the topic as a room with at least five doors or entry points into it. Students vary as to which entry point is most appropriate for them and which routes are most comfortable to follow once they have gained initial access to the room. Awareness of these entry points can help the teacher to introduce new materials in ways in which they can be easily grasped by a range of students; then, as students explore other entry points, they have the chance to develop those multiple perspectives that are the best antidote to stereotypical thinking”. In [6], for each of the five entry points theorized by Gardner we provide a link with the adoption of a role playing game and a concrete example of a possible gameplay situation, based on teaching physics (we argue the approach is applicable to STEM in general). Notably, in 1999 Gardner added a sixth entry point: *Social - Use group settings, role-play and collaborative arrangements,* which perfectly complies with our proposed approach.

In the above scenario, students face with numerous learning opportunities and therefore require intelligent support and guidance. The use of IPAs is proposed as support during the game evolution and each student has its own IPA: they act as learning facilitators and guide the learners in the virtual environment, by explaining topics, answering questions, giving feedbacks, helping the learners to collaborate with others, providing personalized learning support. In fact, as suggested in [7], one of the Artificial Intelligence (AI) grand challenges in education is “mentors for every learner”: IPA combines different abilities including intelligence and pedagogical orientation; they are autonomous and not directly guided by users.

The envisioned VLE partly runs on a central server (e.g., an Interactive Whiteboard) and partly on mobile devices directly provided by the school or owned by the students themselves as depicted in Figure 1. For a detailed description of the platform, the reader can refer to our work [8].

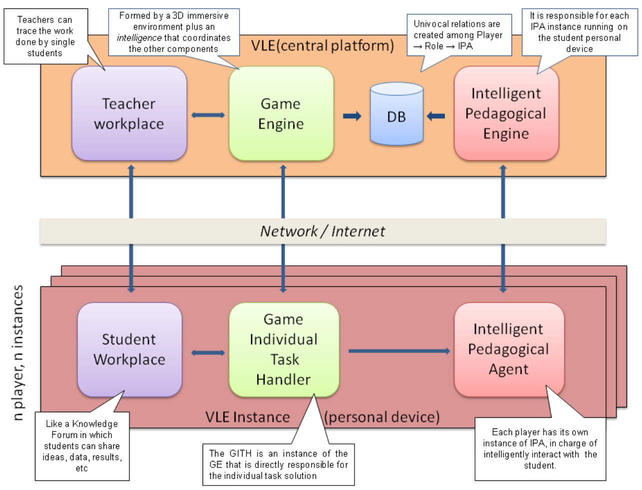

Fig. 1: Platform architecture

B. Use case scenario

As shown in Figure 2, the teacher introduces the scenario to the students and explains the problems that they have to solve during the game. After that, the teacher designates a master that behaves at the same level as the teacher, by following the approach in which a student can “learn how to learn by teaching”; in each session of the game, the master should be a different student, so everyone can experience a role of greater responsibility.

Then, the master with the help of the teacher, can form teams and assign a specific role to each student. The student, from now on, becomes a player with her specific role and her own task as well (depending on the level of the student). In this phase, an IPA is assigned to each student/player that will drive her all along the game. The relation between the student and her IPA should progress all along two paths: the learning aspect (giving tips and advices related to the topics and to the tasks assigned) and the emotional/pedagogy one (the interaction depends on the feelings of the student).

Each student is assigned a task and each single contribution allows her to solve the more general complex problem. The student should solve the task possibly on her own at home (homework) or during classroom lessons, depending on how the teacher would like to organize the work.

The player is invited to share her solution and discuss it with the others. When the team achieves a solution, the master can verify it, and if the provided solution is correct, the game proceeds to the next level.

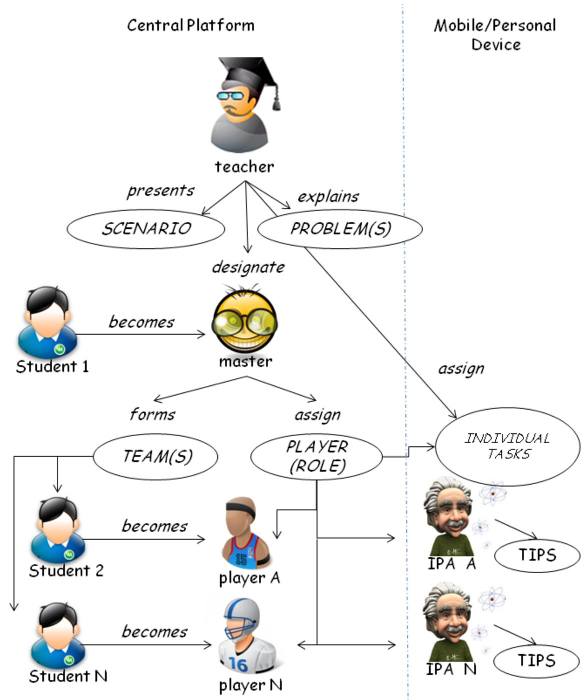

Fig. 2: Use case scenario

C. Game quests and learning patterns

We can consider both games and courses as a system of problem-solving activities. Problem-solving is a process of activities aimed at transitioning from an initial state to a desired goal state, overcoming obstacles, and often developing knowledge [10]. Some types of games explicitly leverage the problem-solving nature of gaming in order to articulate the player experience. This is the case of quest-based games, in which quest systems are used as mechanics to organize game play activities and contextualize them in a coherent narrative frame, defining narrative and activity progression within the game [11][12]. Quest-based games have a primary aim that players must fulfill through achieving concrete objectives associated to quests. Thus, quest-based games are deliberately designed as systems of problem-solving activities aimed at achieving objectives that need to be successfully addressed in order to progress and eventually win.

Gameplay mechanics define the interrelationship and interoperability of the game system elements, the provision of contextual information to the player, and the dependencies between gameplay activities [13].

We have taken the patterns proposed by [14], as base for our gameplay development, and extended them with two more patterns: the quiz structure and the team challenge-based reward as explained in Table 1.

III. EMOTIONAL IPA AS PROOF OF CONCEPT

Figure 3 reports a summary of the state of the art about IPA development in learning context. Two major papers [15][16], from the end of the nineties, introduced the Persona Effect and the concept of the agent like a Social Actor leading to the idea and development of Animated Pedagogical Agent. Most of the recent works try to put together sensor technology (audio/video systems, brainwaves signal, etc) with emotional

TABLE 1: QUEST STRUCTURE AND IMPLEMENTATION

Gameplay patterns	***Explanation***	***Implementation***
Quest structure	The plot is articulated as a sequence of quests. Some parallel/alternate quest choices are foreseen as explained in the *non linear progression* box.	The quest are of three types: 1. Simple problem that should be solved individually (tasks) 2. Complex situation that requires the work of the entire team, coordinated by the master 3. Optional quests inserted by the teacher during game practice
Quiz structure	In some situation the game can progress simply replying to quiz questions with multiple choices.	Students find this structure in some game situation to in which a quick, individual solution is required.
Strategic open-endedness	We provide a series of limited possible alternative strategies to progress in the game. Just one or two strategies are successful while the others are dead-ends.	The diverse possibilities are seen as predetermined doors or choices. When the student select a choice should motivate it, providing a specific answer. If the choice is not correct the student can select an ***Orientation*** tool.
Non linear progression	The non linear progression is not foreseen in the first issue of the game.	Few exception to the linearity of the progression are allowed in some sub-branches of the main plot in which students can choose which stage investigate first.
Orientation	**Big Brain (BB):** is a central brain that contains information and that can be read by the students like a sort of wiki **Simulation Room (SR):** Is a virtual environment linked to the game but external to the game in which the student can practice some game/physics situation **Intelligent Pedagogical Agent (IPA):** when the students seek for short and simple tips can ask to her personal IPA	Each player can: **BB**: Contact the big brain and seek for an explanation **SR**: Enter the simulation room **IPA**: Ask tips to the personal agent **DN**: Do nothing and just try something else!
Individual Challenge-based reward	In each situation points are gained or lost as explained in the next box. Points are gained when the student directly provides the correct answer without using the ***Orientation*** while points are lost when the student use one of the tools.	**BB** → Loose very few points **SR** → Loosing or not points depending on the outcome of the simulation **IPA** → Loose very few points **DN** → Loose more points but have the possibility to arrive faster to the solution
Team Challenge-based reward	In some situation students should discuss (as a team) and provide a common solution to the problem. If the common solution is correct the team gain some points, if the solution is incorrect the team lose some points	Individual and team points are distinct and do not sum. The entity of the point lost/gained depends on the specific tasks and on the ability of the master to coordinate the team. Thus the team score is based on an automatic response of the system (game engine) and on an evaluation by the teacher of the work done as a team.

model (dimensional, categorical) in order to properly recognize and manage user's emotions. Some papers, e.g., [17], put emphasis on the politeness effect and others, e.g., [18] put more research effort on Artificial Intelligence techniques to better model agents' answers and suggest a combination of AI techniques and sensor analysis.

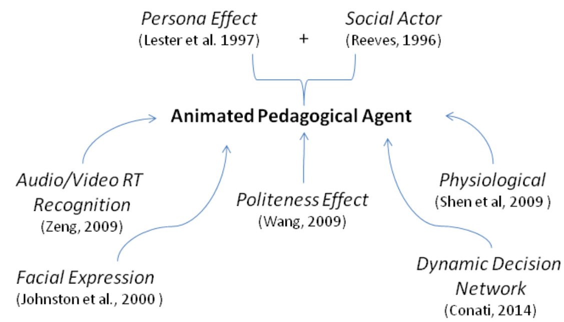

Fig. 3: Schema of the state of the art about agents

In our research, as far as the emotional interaction with students, we adopted a bottom-up approach, by surveying an experimental group of 20 students, from an Italian high school aged 16-17 years (from September 2014 to December 2014), in order to investigate their feeling in a school context. The work done with students has been conducted in collaboration with school teachers from literature and computer science classes. We worked on emotions, starting to analyze what students feel during real school scenarios, like a test session or an oral presentation. Then, for each emotion they express a wished behaviour of the virtual tutor (Pedagogical Agent), a motivational phrase of the tutor, and the facial expression that the tutor should have. A full description of the project and its results are reported in [19]. All the collected emotions have been registered in a database, linked to a possible reaction of the virtual tutor.

Students interact with the IPA via chat expressing their feeling in natural language. Natural language analysis is then performed on students' phrases to detect their emotion. More in details, the developed Android application works as it follows. The student registers to the application and once she is logged, she can choose among a list of topics and available IPAs (with different aspects). Once the topic has been chosen, students can chat with the IPA simulating a natural dialogue about the topic covering pedagogical and learning aspects.

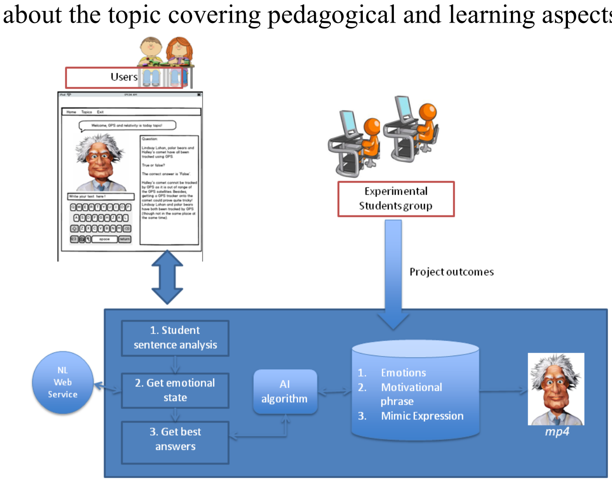

Fig. 4: Android application overview

The system allows the user to freely express her thoughts in textual form. The IPA is able to guess student emotions by exploiting a Web service that analyzes the sentence and returns an emotional state. The user gets back an adequate answer: each possible answer corresponds to a pre-registered mp4 file in which an animated avatar has been modelled following the instructions given by the students in the previous phase of the study (mimic expressions and motivational phrases).

Beside the emotional relation between the student and the IPA, the student is able to chat with the IPA about the subject of study that is explained via textual message: the best answer to learning questions is provided using a specific AI algorithm, starting from [20] and improving it.

This Android application has been presented (after a selection process) at the Science on Stage Festival 2015 (cf. `http://www.science-on-stage.eu/page/display/4/14/0/festival-2015`) and raised a lot of interest from teachers and researchers in the field of new technologies in schools. Clearly this Android application is only an initial step towards the ambitious objectives of our research. It should be enhanced in order to *(i)* allow students and IPA to interact more naturally (e.g., through vocal interaction via ASR/TTS technologies), *(ii)* dynamically synthesize and present emotions to students, and *(iii)* be integrated with the remaining of the VLE (cf. the overall architecture in Figure 1). In addition, our future work includes completing the overall platform, and to validate it through an entire semester in an high-school in Italy, in order to demonstrate its efficacy as a supporting tool for teaching physics.

IV. Conclusions

The research discussed in this paper wants to address several open questions related to the use of new technologies in teaching practice. Good technology can enhance learning? Do virtual tutors make students more confident? Can we support inquiry based learning through the use of games? So far we have evidence, also from other research projects, e.g., [15][17][18], of enthusiasm from the student point of view in the use of games and virtual tutors. But, do we have the same enthusiasm from teachers? Our answer to this question is a new challenge for the future: make teachers able to provide their own content, using the technologies powered by us.

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