Game@School. Teaching Through Gaming and Mobile-Based Tutoring Systems

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Abstract. 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). We additionally present an Android application that uses the IPA as a standalone application as an initial step towards the realization of such an architecture.

Keywords: Virtual Learning Environment · Intelligent Pedagogical Agent · Serious game

1 Introduction

In the past years, the rapid growth of the game industry has aroused wide interest, particularly among educational technology researchers. It is known that the possibilities to use digital games in education have been considered since the 70s, even if actually the quality of produced games has not met the expectations of educators and the use of games has not become as general as expected [5]; on the other hand we find commercial games used for learning purposes, famous examples are PORTAL2[1] or MINECRAFT[2].

In this context, we followed the idea to integrate the most up-to-date technologies in new teaching trends, namely Virtual Learning Environments (VLEs, [2]) and Intelligent Pedagogical Agent (IPAs), as deeply investigated in [10]. The VLE is developed as an immersive 3D environment and the game is a role playing 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 use of IPAs is proposed as support during the game evolution and each student has her own IPA: IPAs act as learning facilitators and guide the learners in the virtual environment. In fact, as suggested in [13], one of the Artificial Intelligence (AI) grand challenges in education is "mentors for every learner".

[1] http://www.teachwithportals.com/.
[2] https://minecraftedu.com/.

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In this paper, after introducing in Sect. 2 some background concepts about learning that motivates our approach, we present the pillars of our game and its architecture in Sect. 3. Then, in Sect. 4 we focus on the initial Android app which provides the mobile IPA (as described in the architecture) to be used by students during learning, and a preliminary validation in real teaching contexts in Sect. 5. We conclude by comparing with relevant work in Sect. 6 and provide some final remarks in Sect. 7.

2 Background

The idea of helping students during their learning through a different way wrt. the classical approach finds support in many psychological studies and previous work. In particular, Howard Gardner already in 1983 theorized [3]: "My own belief is that any reach, nourishing topic - any concept worth teaching - can be approached in at last five different ways that roughly speaking map onto the multiple intelligence. 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 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". For each of the five entry points theorized by Gardner, as reported in Table 1, we provide a motivation for the adoption of a role playing game and a concrete example of a possible game-play situation, based on teaching physics (we argue the approach is applicable to STEM in general). Notably, in 1999 Gardner added a sixth entry point [4]: *Social - Use group settings, role-play and collaborative arrangements*, which perfectly complies with our proposed approach.

The learning objectives of the game are: the physics aspects of a space mission (gravity, propellent, orbits, trajectories, etc.); which are the conditions in which humans can live (gravity, oxygen, pressure, temperature, etc.) and many other interdisciplinary aspect of the proposed topic. The learning aspects are well integrated in the game mechanics. There are simulation rooms where players, depending on their roles, can solve problems, simulate certain conditions, etc.

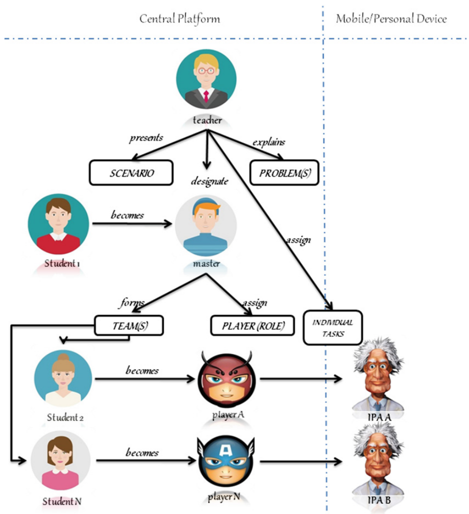

Fig. 1. Use case scenario

As shown in Fig. 1, 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

Table 1. Gardner' s theory of five entry points and role-playing game

Howard Gardner five entry points	Plot and roles' examples in the game
Narration entry point (read or tell a story)	The game has a plot (tell a story) that evolves during the game. The story has been designed to address several physics problem linked to a space mission. In addition several physics tasks are proposed in an interdisciplinary way. *Story*: The Near Earth Object, classified as 2017 Titan, will impact the Earth 25 May 2017. A huge team of scientists is studying 2017 Titan, but unfortunately there is no way to destroy the asteroid before it will impact the Earth. The best way to avoid the disaster is to prepare a space mission and colonize a new planet. The team challenge is to choose an exo-planet to colonize among three possible ones
Logical-quantitative entry point (provide data, use deductive reasoning, examine numbers, narrative plot structure, cause and effect relationship)	During the game, students should solve problems and specific assigned tasks. *Mathematicians*. To perform a flight to one of the exo-planets, a vehicle must first escape from the Earth. Achieving the right speed, however, is only part of the problem; other factors must be considered, e.g., the Sun's gravitational field and the motion of the Earth about the Sun. You should trace the trajectory to the three exo-planets and share your results with the engineers
Philosophical entry point (big questions about reasoning and the way of reasoning)	Students should consider pros and cons of every possible solution. They should discuss all together and understand the implications of their choices. *Astrobiologists*: you should evaluate the consequences of colonizing a planet. What to do if the planet is already inhabited? How to protect the local environment?
Aesthetic entry point (emphasize sensory, activate aesthetic sensitivities)	The information/social space is explicitly represented as a 3D immersive world. *Space artists*: you are a member of the International Association of Astronomical Artists (IAAA). You should draw the vexillum of the space mission
Experimental entry point (hands-on-approach, dealing directly with materials, simulation, personal explanations)	The game requires that students take actively part to the story by solving problems and finding solutions. The team discussion is also a must. *Physics scientists*: you need to calculate the gravity on the three planets. You should make some comparison with terrestrial gravity and suggest which is the best planet to colonize. Communicate your results to other team members, in particularly to the astrobiologists and discuss with them. Can we survive in those gravity condition?

master (among the students) that behaves at the same level as the teacher, by following the approach in which a student can "learn how to learn by teaching". Then, the master with the help of the teacher, can form teams and assign a specific role to each student. Each student, from now on, becomes a player with her specific role and her own task as well. 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). IPA behaviour has been implemented and tested in the Android app, as explained in Sect. 4.

3 Overall Architecture

The envisioned role playing game 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. In our current implementation, the VLE functionalities, related to class management and handled by the teacher, are built on top of Opedia[3], and are available on the interactive whiteboard. The VLE indeed allows teachers to manage games, players, teams, etc. A player is a student that has already registered and that has a previously assigned role, (see Fig. 1), each player is part of a team, formed by 5/6 players.

The main component that runs on the whiteboard is the Game Manager engine that control the Unity Server, the Chat Server and the Knowledge Forum Server. Information and logs about game sessions and related activities are stored on the whiteboard as well. The game has been conceived to be used in classes but can be used at home as well, therefore some services should be always up and running (like login/register, sentiment analysis, etc.). Information about students/players is stored in a database. The game is developed using Unity 3D as a multi-players game, that is the reason why there are both Unity server and client components. The components that run on the mobile device, in addition to the Game Manager client, concern all the additional functionalities of the game that can be used by the student, as further explained below. Figure 2 shows the overall architecture and its main components.

For each team there is a shared space, displayed on the interactive whiteboard, in which are shown: the list of players, the live chat among members of the same team and the Knowledge Forum, as depicted in Fig. 3. If the teacher touches a player, all the related info (as role, assigned tasks, individual score, level, power, etc.) are shown. The Knowledge Forum (KF) gives the possibility to the student to add notes about the game, the assigned tasks, or any learning aspect of the game. The added notes appear on the shared VLE and are visible to other students and teacher. The Big Brain (BB) is a peculiar type of help in the game: if the player uses this kind of help, she could gain points instead of losing them. In order to gain points, the player should ask the right questions to BB. For each session just few (2 or 3) questions are foreseen.

[3] http://www.opedia.it/.

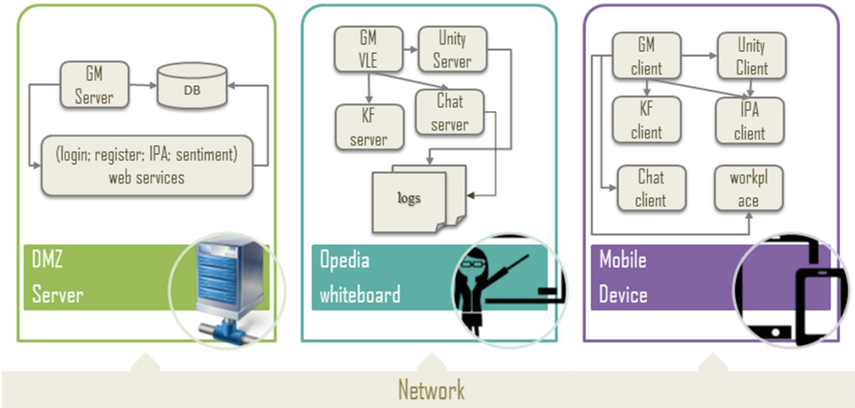

Fig. 2. Game architecture

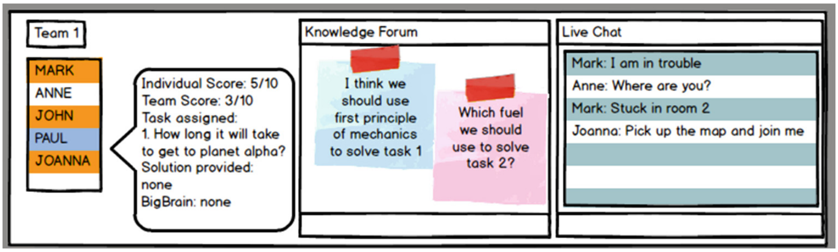

Fig. 3. Shared VLE view

Players are able to chat during a game session. The chat is among team members and it is visible on players' mobile devices and on the shared VLE. The IPA live chat gives the possibility to the student to chat with her virtual tutor that should guide her trough the emotional and learning aspect of the game. In the workplace, players can analyse their tasks, simulate solutions, read notes about task topics and provide solutions to the assigned tasks.

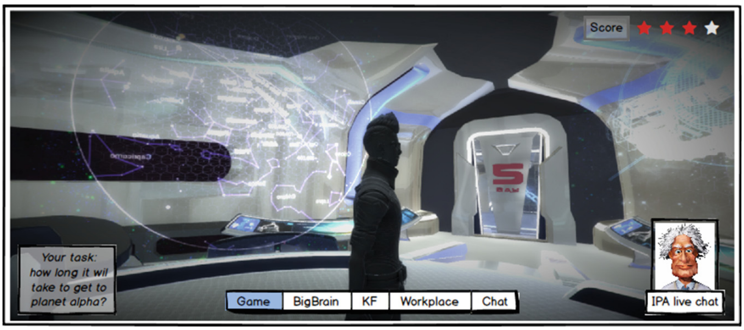

Fig. 4. Mobile device game view

Players play on their mobile devices, as shown in Fig. 4. In the right corner, there is the *assigned task* panel; the central bar lists all the available functionalities; in the left corner, there is the *IPA live chat* panel. In the top left corner, there is the individual score. The IPA live chat is a core part of our research: players can chat with their virtual tutors; the system allows the player to freely express her thoughts in textual form. A more detailed description of how the developed IPA works is reported in Sect. 4.

4 The Android App

In order to verify our approach, during the development of the whole game, we have realized a stand alone application in Android that uses the IPA as interlocutor while studying specific contents. 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. The app follows a game approach, in fact the session starts with an initial quest to which the student should answer at the end of her learning path. The score of the game depends on how many questions the student asked in order to devise the solution. Some Android application screenshots are reported in Fig. 5).

Students interact with the IPA via chat, expressing in natural language. Natural language analysis is then performed on students phrases to detect their emotions, by exploiting a back-end Web service that analyses the sentence and returns an emotional state: it returns a label representing the identified sentiment (positive, negative, neutral), along with a numeric score ranging from strongly positive (1.0) to extremely negative (−1.0). Depending on the label and on the numeric score the user gets back an adequate answer: each possible

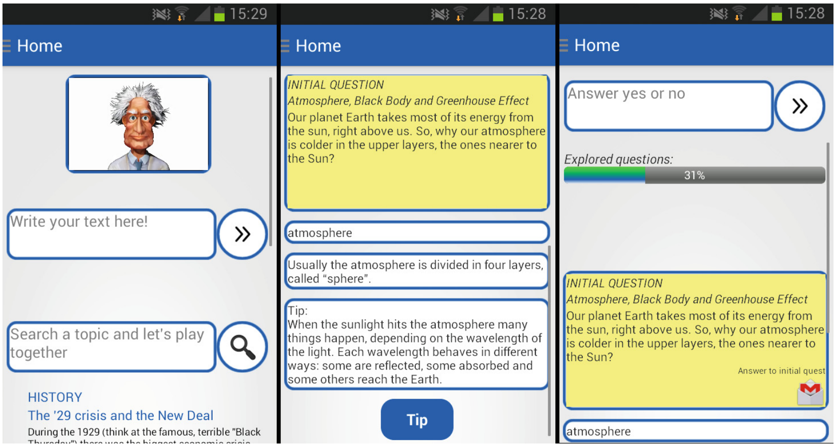

Fig. 5. Android app screenshots

answer corresponds to a pre-registered mp4 file in which an animated avatar has been modelled (mimic expressions and motivational phrases). For example, when player logs in, avatar says "Hello, welcome to our app. How are you today?". The system analyses the player sentence and reply something like "I am happy to ear that you are fine" in case of extremely positive label or "I am sorry that you are not fine" in case of extremely negative label. This approach aims to establish an empathic feeling between the student and her virtual tutor.

In order to collect emotions, expected IPA behaviors and motivational phrases, we worked with a group of 20 students from an Italian high school aged 16–17 years old (target age of our serious game). The work done with students lasted three months (from September 2014 to December 2014) and has been conducted in collaboration with teachers from literature and computer science classes. We divided the work into two main parts: a study of the emotions in school context and the prototyping of animated agents, as described in [12]. The results of the study have been used to model the avatar and his reaction.

In addition to the emotional relation between the student and the IPA, the student is able to chat with the IPA about the subject of study via textual messages: the best answer to learning questions is provided by using a specific AI algorithm, starting from [8]. As a matter of fact, while in state-of-the-art games, the user usually interacts by choosing a sentence among a set of predefined possibilities, our system allows the user to freely express his thoughts in textual form and provides the user with an adequate answer (selected from a database of answers provided by an expert). The core of the AI algorithm is an implementation of Naïve Bayes Text Classification [7], which is a probabilistic classification method based on Language Modelling under the hypothesis of words conditional independence (unigram or bag of word model). The first task consists in a sentence lemmatization, which transforms all the terms of the sentence in a form suitable for word analysis and computation. We then evaluate the Interrogative/Adjective Pronoun (IAP) of the question, in order to assign a higher classification score to the sentences from the database with a matching IAP. Instead of excluding all the sentences in the database with a different IAP, we just penalize them with a lower classification score; in fact it might happen that an answer might be the best one to respond to the user's question even if each of the expected questions that were associated to it in the database had a different IAP. We then proceed with the Naive Bayes Text Classification, and filter the result by applying the threshold criterion. If the answer passes the test, then it will be returned to the player, otherwise the answer will be replaced with a verbal message of the avatar like "Sorry, there is no adequate answer to your question". Threshold criterion have been verified and tuned with real test sessions.

5 Preliminary Evaluation

In order to evaluate the use of the Intelligent Pedagogical Agent, we tested the Android application in real schools. The app came with two different learning paths: one in STEM, in particular physics (the terrestrial atmosphere) and one in humanities, in particular history (the new deal). Those two learning paths have been developed by field experts. Each student was free to choose the preferred topic.

Appreciation, usability and learnability of the Android app have been specifically assessed in three experimental sessions. The first run of test validation occurred the 19 November 2015 (11 students, all males, aged 17–18), the second run occurred the 20 of January 2016 (16 students, two female, aged 17–18). After a preliminary evaluation of the first two test runs, we calibrated the AI algorithm lowering the threshold for the response to the asked question. The third run occurred the 8 February 2016 (13 students, 8 males and 5 females, aged 17–18). In all three runs, students were able to play with the application roughly 40 min (a bit less of a standard lesson time); we just asked them to play with the application asking question to the IPA about the subject of study. After that they compiled a questionnaire that has been structured in three main sections: liking, usability and learnability.

Appreciation. The first set of questions aimed at understanding if students like the idea of a personalized learning path and the possibility to ask free questions guided by a virtual agent: 75 % of students like this possibility. The aspect of the empathetic guide was felt as well: 68 % of students liked the idea to have an empathic guide and would like to chat also about personal matters. 68 % of students enjoyed the app and would recommend it to others, even if just 56 % of them perceived it as a game. 50 % declared the app is more effective for STEM subject while the other 50 % per cent said both STEM and humanistic.

Usability. It emerged that 68 % finds the interface and the touch screen function clear. Just 50 % of the students used the side menu and the majority of them declare they wish to add other functionalities. Most of the interviewed disliked the scientist avatar (70 %) while liked the young girl (72 %).

Learnability. Tests revealed that 78 % of students thought avatar explanations are clear and declared that provided answers are in line with asked questions. 64 % declared tips were useful. We asked how many questions they asked to the avatar before quitting the game: 46 % gave up after few questions, 34 % ended the game after roughly 10 questions, 15 % around 20 and just 1 student declared to ask more then 20 questions. Those results were obtained in the first two runs. That is mainly because very often pertinent questions received no answers due to the very high threshold settings of the AI algorithm. However, after AI algorithm threshold calibration, in the third test run we obtained that 38 % ended the game after roughly 20 questions while 30 % gave up after few questions. So we had an increment of roughly 20 % in content exploration.

6 Related Work

An example of VLE is the one described in [9]. The research is based on multiple pre-existing projects which embody virtual technologies. All of them have their respective benefits, and the goal of the project was to fuse them into a new collaborative learning environment. Within such a collaborative environment, those tools provided the opportunity for teachers and students to work together as avatars as they control equipment, visualize physical phenomenon generated by the experiment, and discuss the results.

Concerning emotional learning, [1] presents an approach to a possible modelling of user affect designed to assess a variety of emotional states during interactions: knowing the details of a user's emotional reaction can enhance a system capability to interact with the user effectively. Instead of reducing the uncertainty in emotion recognition by constraining the task and the granularity of the model, the proposed approach explicitly encodes and processes this uncertainty by relying on probabilistic reasoning. The authors discuss their model in the context of the interaction with pedagogical agents designed to improve the effectiveness of computer-based educational games. They also introduce Dynamic Decision Networks and illustrate how they can be used to enable pedagogical agents for educational games to generate interactions tailored to both the user's learning and emotional state. [14] presented a pedagogical agent capable of active affective support, guided by the logic which integrates the learner's cognitive and affective states. They developed an algorithm for feature tracking which utilizes a combination of common image processing techniques, such as thresholding, integral projections, contour-tracing and Haar object classification. The experiment results indicate a range of preferences associated with pedagogical agents and affective communication. According to the authors, affective interaction is individually driven, and they suggest that in task-oriented environments affective communication carries less importance for certain learners. This paper inspired us in the modelling of the avatar in a process of reverse engineering. In fact, the animated avatar is a preregistered mp4 file in which the avatars face expresses emotions. [11] presents a system that embodies the idea of virtual humans that act and interact like humans, bringing social elements in the interaction: a couple of twins that are virtual teachers in the Museum of Science in Boston designed to engage visitors and raise their awareness and knowledge of science. The twins have some aspects that were built in advance, and some that operate in real time as the user interacts with them. The aspects built in advance include the character bodies, animations, textual content, and spoken output. The speech recognition, natural language understanding, and dialogue management decisions of what to say are computed in real time, as is the scheduling and rendering of spoken and gestural outputs. Speech recognition, natural language understanding, and dialogue policies also make use of knowledge sources constructed in advance, using supervised machine learning.

In [8], the system allows the player to express himself in natural language. The system processes users' input sentences and returns the best answer among a set of possible stored answers. The communication is implemented through an NLP algorithm based on an ad hoc text retrieval problem solver and on a Naive Bayes text classifier with an inner product-based threshold criterion. The algorithm implemented in the system is a variation of a text retrieval algorithm. We extended the work done in this paper has reported in paragraph 4.

7 Concluding Remarks

The proposed use of IPAs in the game, and the related Android app, follows an inquiry based approach. It starts by posing questions, problems or scenarios rather than simply presenting established facts or portraying a smooth path to knowledge. In the app, the initial quest posed to the student is a sort of incipit that serves to encourage her to start reasoning about a specific topic of study. Then, students ask free questions to the virtual tutor, designing their specific learning path and not following a predetermined one. As previously reported, 75 % of students like the idea of a personalized learning path and the possibility to ask free questions.

We also found that 68 % of students liked the idea to have an empathic guide. It is important for teachers to create a positive, emotionally safe environment to provide for the optimal learning of students. Learning how to manage feelings and relationships constitutes a kind of "emotional intelligence" that enables people to be successful. Emotional intelligence expands on Howard Gardner's theory of multiple intelligences. Although the interplay of affective and cognitive processes always underpins learning outcomes, affective interaction sometimes may need to remain in the background, as found in other study [14]; whatever the case, an Intelligent Tutoring System should let the user decide on the level of affective feedback. That is the case of our game in which the player can choose if and when chat with her IPA.

In summary, we believe our Android application, although only preliminarily validated, gave us a proof that the developed IPA could be an important plus for the envisioned role playing game. In the future we are planning to asses the learning outcome of the app comparing control and experimental group.

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