Using role-playing game in a Virtual Learning Environment for a new approach to physics classroom lessons.

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Abstract
Although the term “digital native” by Prensky is not appreciated by all pedagogical researchers, it perfectly describes the nowadays students that continuously deal with technology. Over the last ten years, the way in which education and training are delivered has considerably changed due to the introduction of new technologies. One of them, very promising, is Game-Based Learning. The work proposed in this paper stems from the experience of the last teaching years to students aged 14-15: the physics lessons given using games, competitions and group collaboration are much more effective than the more traditional frontal lessons. In this work, we propose a constructivist approach in which youngsters are called to be the main actors of the learning process and in which a personal construction of their knowledge is a must, starting from their needs and their motivations. Role playing games fit very well these requirements and in order to reinforce this didactic (and non technical) choice we motivate it by referring to the Gardner’s theory of five entry points (strictly related to his theory of multiple intelligences) with examples of possible role playing game implementations. The approach that we propose in this work combines two fundamental aspects in the state of the art of e-learning panorama (that commonly are not combined): the integration of Intelligent Pedagogical Agents into Virtual Learning Environments.

Keywords
Intelligent Pedagogical Agent, Virtual Learning Environment, Game-Based Learning, role-playing games, classroom practice.

Introduction
Over the last ten years, the way in which education and training are delivered has considerably changed. 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 Game-Based Learning (GBL). The term game is quite ambiguous, which means that researchers, game designers, parents, students, teachers, etc. have a different concept of game; games refer to a lot of different game formats (video games, location-based games, board games, etc.), game genres (strategy games, edutainment game, role playing game, etc.) and game dynamics (competition, exploration, resource management, etc.). To avoid confusion about games in a learning context, game-based learning (or teaching) is often combined (or used as synonymous) with the term “serious games”. We recall here some definitions of serious game and game-enhanced learning (Dyer 2013):

- According to Corti (2006), serious game “is all about leveraging the power of computer games to captivate and engage end-users for a specific purpose, such as to develop new knowledge and skills”;
Zyda (2005) defines serious games as “a mental contest, played with a computer in accordance with specific rules, that use entertainment to further government or management education, health, public policy and strategic communication objectives”;

Sande (2006) defines a serious game as “a game in which education (in its various form) is the primary goal, rather than entertainment”.

GBL is a branch of serious games that deals with applications that have specific learning outcomes. Generally, such games are designed in order to balance the subject matter with the game-play and the ability of the player to retain and apply subject matter to the real world. In our work, we can see games as inquiry-based laboratories in which participants are able to imagine, engage with, and reflect upon their experiences. Games are intended as scenarios, according to Hangoj (2013). A scenario directly refers to the dynamic, future oriented models for possible actions that are embedded in game designs. Games are well suited for developing students’ scenario competence, which can be defined as the ability to imagine, enact and reflect upon game-specific choices and their consequences.

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 aspect, to scenario-based and every day practice. On the basis of Hangoj (2013), we adopt the idea that there is a complex translation involved in using games for educational purposes and thus we can see GBL as a dynamic interplay of four knowledge practices, as depicted in Figure 1.

![Figure 1: Game based learning as interplay of knowledge practice](image)

In the past years, the rapid growth of the game industry has aroused wide interest, particularly among educational technology researchers as well as digital learning material producers and publishers. It is known that the possibilities to use digital games in education have been considered since the 70s. Nevertheless, the concrete and scientific ambitions to produce high quality educational games have been quite minor (Katamo 2013). 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. However, the rapid growth of the entertainment game market has reawakened the interest of educational researchers and producers, and game studies have rapidly developed into an important interdisciplinary research field as well as a nascent academic discipline. So, it seems that games will get another chance to prove their usefulness in computer-assisted learning (Katamo 2013).

In this context, our work aims at developing a game in order to teach STEM subjects, in particular physics. The game that we are designing and going to develop takes into account all
the aspects of GBL previously introduced. In addition, and more importantly, we try to integrate the most up-to-date technologies in this field like *Virtual Learning Environments* (VLEs, which add value to the educational process by giving new possibilities and computational-richness support) and *Intelligent Pedagogical Agents* (IPAs, which provide personalized instructions, increase learner motivation, and act pedagogically on behalf of the learner). In this work, we propose that each student has her own IPA (on her own personal device) that guides her throughout the role-playing game. The recent use of 3D immersive VLEs has shown effectiveness in improving the motivation towards learning; therefore we propose it as storyboard for the role playing game.

**State of the art**

**Intelligent Pedagogical Agent**

The first grand challenge of Artificial Intelligence (AI) in education, as suggested by Woolf (2013), is *mentors for every learner*. This focuses on applying the finding of learning science to the design and building of systems that can interact with learners in natural ways and act as mentors to individuals and collaborative groups when a teacher is not available. The concept of Intelligent Pedagogical Agent can be described as (Soliman 2010):

- **Agent**. The agent is a software component that can act by itself in the environment based on a goal.
- **Intelligent**. An intelligent agent applies distributed AI methods to achieve goals. Intelligence can be characterized as the agent’s ability to learn from the environment and change the behavior accordingly to achieve the design goals.
- **Pedagogical**. In this context, the intelligent agent should possess pedagogical abilities to achieve educational objectives.

In our work, 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 assigned tasks) and the emotional/pedagogy one (giving advices depending on the feelings of the student). Emotions are important for students in two major ways. First, emotions have an impact on learning. They influence our ability to process information and to accurately understand what we encounter. For these reasons, it is important for teachers to create a positive, emotionally safe environment to provide for the optimal learning of students. Second, learning how to manage feelings and relationships constitutes a kind of “emotional intelligence” that enables people to be successful (Darling-Hammond 2014).

Some researchers focus their attention on making educational games more pedagogically effective by making them capable of providing interactions tailored to each student’s needs and targeted at stimulating learning when necessary. These systems are named Intelligent Tutoring Systems (ITSs). Here we focus on ITSs that are developed as agents and we disregard ITSs that have different forms. Although there is well-established research on building student-adaptive computer based educational tools, still a few research activities have focused on electronic educational games. In the approach followed by Conati (2004) there are two main challenges, namely (i) in educational games it is especially difficult to assess students’ knowledge and learning from the interaction with the game, because often game actions do not have a direct connection with a student’s understanding of the underlying domain; and (ii) how to provide individualized interventions that trigger learning, without interfering with the high level of engagement that educational games usually trigger precisely because they do not remind students of traditional educational activities. The game used in the study by Conati is Prime
Climb that is an educational game devised by the EGEMS (Electronic Games for Education In Math and Science) group at the University of British Columbia. Mori (2013) presents a natural language communication system that has been developed to support effective communication without disrupting the player flow experience while gaming. In most cases the in-game dialogues consist in the ability of the player to choose one sentence among a limited set of sentences that were prescript by the game author. The system proposed by Mori conversely allows the player to express himself in natural language. Systems that use natural language algorithms are typically referred as Dialogue Management Systems (DMSs). They exploit the automatic management of dialogues between the user and the computer controlled Non-Player Characters (NPCs), which are the characters controlled by the system itself. The system processes users’ input sentences and returns the best answer among a set of possible answers stored in the NPCs’ knowledge base.

Virtual Learning Environment
According to Dillenbourg (2000), a Virtual Learning Environment (VLE) must comply with some specific rules:
1. A VLE is a designed information space. For learning environments, the functional requirements are numerous and have not been yet systematically studied. Anyhow here are a few examples: Using information in educational interactions; Multi-authoring; Indicating information source; Maintaining information; Following technical evolution; Sharing information with the world.
2. A VLE is a social space. What is specific to virtual environments compared to any information space is that it is populated. The users are inside the information space and see a representation of themselves and/or others in the space. As soon as students see who else is interested by which information, the space becomes inherently social.
3. The virtual space is explicitly represented. The representation of the learning environment ranges from text-based interfaces to the most complex 3D graphical output. The key issue is not the representation per se, but what the students actually do with this representation.
4. Students are not only active, but also actors. The notion of a learning activity in VLEs refers to something richer than in individual courseware, closer to the notion of project. The difference between other constructivist environments and what virtual environments potentially are can be described as making students not only active, but also actors, i.e. members and contributors of the social and information space.
5. VLEs are not restricted to distance education. The use of VLEs can influence the way teachers teach and thereby contribute to renew teaching methods in classroom practice.
6. VLEs integrate multiple tools. A physical learning environment generally integrates courses, resources (libraries), formal communication (boards) and informal communication (cafeteria), an administration, etc. Similarly, a VLE integrates a variety of tools supporting multiple functions: information, communication, collaboration, learning and management. The idea of environment includes this notion of integration.
7. Most virtual environments overlap with physical environments. VLEs do not only integrate a variety of software tools but also integrate all the physical tools that can be found in a classroom.

In order to further assess added pedagogical values of VLEs, we can compare with ITSs; in ITSs, the main characteristic is the removal of human intervention by the use of AI methods. Whereas ITSs are intended to provide pedagogical functions through personalization, sequencing, and others, their direct benefits are a focus on individual uses as direct
consequences of the removal of the human tutor. But so far, they lacked the rich 3D visualization aspects that are available in recent 3D VLEs. Furthermore, a VLE provides more collaboration and exploration-based learning opportunities and can be much more open and flexible than the individualistic ITS.

The game
Our main proposal is a VLE 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 addition, a designated student becomes the master, who is the coordinator of the activities and tasks of her team. In order to success, all the players should work to obtain a common objective and a common goal. The success of the single individual coincides with the success of the entire community (the class). 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.

<table>
<thead>
<tr>
<th>Howard Gardner Five Entry Points</th>
<th>Why role playing game</th>
<th>Examples (based on the same storyboard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narration entry point (read or tell a story)</td>
<td>The VLE in the game coincides with a plot (tell a story) that evolves during the game</td>
<td>Conquer an exoplanet and colonize it</td>
</tr>
<tr>
<td>Logical-quantitative entry point (provide data, use deductive reasoning, examine numbers, narrative plot structure, cause and effect relationship)</td>
<td>During the game, students should solve problems and specific assigned task.</td>
<td>Form a team and solve the following single task: (a) how long the journey will last; (b) how much fuel is needed; (c) gravity on the new planet (i.e., the exoplanet)</td>
</tr>
<tr>
<td>Philosophical entry point (big questions about reasoning and the way of reasoning)</td>
<td>Students should consider pros and cons of every possible solution. They should discuss all together and understand the implications of their choices.</td>
<td>Evaluate the consequences of colonizing a planet: (a) what to do if the planet is already inhabited; (b) how to protect the local environment</td>
</tr>
<tr>
<td>Aesthetic entry point (emphasize sensory, activate aesthetic sensitivities)</td>
<td>The information/social space is explicitly represented as a 3D immersive world</td>
<td>The 3D immersive world can be partially customized and students can choose the preferred configuration</td>
</tr>
<tr>
<td>Experimental entry point (hands-on-approach, dealing directly with materials, simulation, personal explanations)</td>
<td>The game requires that students take actively part in the story by solving problems and finding solutions. The team discussion is also a must.</td>
<td>Simulate a different gravity on the new planet and: (a) discover which force we need to lift a stone; (b) how heavy we are</td>
</tr>
</tbody>
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“Role-playing games offer people the chance to actively take part in their own alternate expressions of identity, exploring parts of themselves that were previously submerged or repressed by the dominant culture and the requirements of daily roles. Role-playing games exist in many forms, from virtual role-playing to tabletop to ‘live action’. While each type of role-playing offers a unique experience, these games provide a compelling escape from the mundane reality, attracting millions of players worldwide. Unlike the passive experience of watching a film or reading a book, these games encourage players to actively take part in the adventure, sometimes even developing their own stories and characters. RPGs also offer a safe, relatively
consequence-free space where players can develop certain aspects of themselves. Through role-playing, players learn how to inhabit the headspace of someone other than their primary ego identity, offering them the chance to develop a stronger sense of empathy. RPGs help encourage a sense of community, by teaching individuals to function as a group. Experiences transpiring in RPGs allow players to develop a deeper understanding about themselves and one another during the course of the adventure.” (Bowman 2010)

Another important aspect is Gardner theory of multiple intelligence and, in particular, his theory of entry points (Gardner 1999): “My own belief is that any reach, nourishing topic - any concept worth teaching - can be approached in at least 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”.

Combining such aspects, we elaborated Table 1 in which we report the five entry points theorized by Gardner and, for each one of them, we give a possible link with the adoption of a role-playing game (second column). In the third column, a concrete example of a possible actuation is given. In the above scenario, it is expected that the students have great flexibility, faced with numerous learning opportunities and therefore require intelligent support and guidance. The use of IPAs is proposed as support during the game evolution: 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.

**Use case scenario**

As shown in Figure 2, the teacher introduces the scenario and explains to the students the problems that they have to solve during the game. Each problem is formed by several tasks. After that, the teacher designates a master. The master is a key role for several reasons; from a pedagogy point of view, the master behaves at the same level of the teacher and this match Chan and Baskin approach in which a student can “learn how to learn by teaching”; from a learning point of view, the master learns not only the involved topics, but also the best strategy to be adopted for an optimal solution. In each session of the game, the master should be a different student, so everyone can experience a role of major 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. Therefore the student has her virtual tutor 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 (giving advices depending on the feelings of the student). Each student is assigned a task to be solved. Each task is part of a more general problem and each single contribution permits to solve the more general complex problem. The student should solve the task possibly by 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 with the others. Team discussion is useful in order to succeed in the problem solution and will help the
class to cooperate and collaborate. The teacher can intervene on specific topics related to the problem solution, and can help the master, if necessary, to coordinate the discussion. When the team achieves a solution, the master can verify it, and if the provided solution is fine, the game proceeds to the next level. Before affording the next problem, the students can play and construct pieces of the scenario, useful for the storyboard to continue.

**Figure 2:** Actors involved, their roles and the actions to initiate the game

**System Architecture**

**Figure 3** shows the three main components that run on the central platform, namely the Game Engine (GE), the Intelligent Pedagogical Engine (IPE), and the Teacher Workplace (TW). For each student/player, there are the corresponding components on her personal device, namely the Game Individual Task Handler (GITH), the IPA and the Student Workplace (SW). VLE and devices are connected through the Internet.
**Game Engine component.** The GE component is formed by the 3D immersive environment plus the intelligence that coordinates the other components of the system. In particular the GE will be responsible for:

- **Managing the players and the assigned tasks.** Each player as a role and depending on the role a specific task is assigned. A task can be seen as a problem to be solved from a teaching point of view and as an objective to achieve from the gaming point of view.
- **Interacting with the teacher’s workplace.** The game engine should send logs about the player activity to the teacher’s workplace.
- **Communicating with the DB.** Once a univocal relation is created:  
  \[ \text{Player} \rightarrow \text{Role} \rightarrow \text{IPA} \rightarrow \text{Tips} \]
  
  the GE should be able to retrieve the correct information for the single player during the game evolution.
- **Instantiating the individual task.** A single task for each player should be created as an instance and sent to the GIT component.

**IPE component.** The IPE is responsible for each IPA instance running on the student personal device. This component is in contact with the DB in order to retrieve the correct tips for each player. All the Agents possible replies are registered in a database linked to a school situation and a possible reaction of the virtual tutor (namely a facial expression and a motivational phrase, that is not verbal but that is a preregistered animated avatar). The students interact with the IPA via chat expressing their feeling in natural language. Natural language analysis is then performed on students phrase to detect if their emotion is positive, negative or neutral. Then, the
tutor will give the best answer to the student. The best possible answer, consist of the combination of different information:

• Detection of school situation via the game scenario
• Natural language analysis of student phrases.
• Classification of student in positive and negative faces.

The combination of these factors according to a specific algorithm determines the possible best answer.

Teacher’s Workplace component. The teacher’s workplace is a virtual environment in which there is a matching between the student and her role in the game. Teachers can trace the work done by the single student looking at how long the student played the game, the individual solution to the assigned task, how many tips was asked, how was the relation with the IPA, etc. This component is accessible to the teacher and there are only information strictly related to the game activity.

Game Individual Task component. Each student/player has assigned an individual task, that is the reason why on the personal device the student has the GIT component. While the central platform controls the entire game via the GE, the GIT is an instance of the GE that is directly responsible for the individual task solution.

Intelligent Pedagogical Agent component. On the personal device we have the IPA that directly talk to the central component, the IPE. The IPA ask to the IPE not only tips related to the individual task solution but also what concern the intelligent behavior of the agent.

Student workplace component. The student workplace should be intended as a sort of Knowledge Forum that provides students and teachers with a collaborative space in which to share ideas and data about the game, analyze individual results, discuss questions, cite reference material, etc. The student workplace and the teacher workplace are strongly bound since the teacher can intervene; act as a moderator and monitor student activity.

Conclusion
Nowadays, we deal with digital native students, and therefore we need to follow them on their digital requirements; on the other side, learning remains a slow process that requires curiosity, devotion and time to absorb and elaborate information. From a pedagogical point of view, a role-playing game, even if using a virtual learning environment, provides enough time to elaborate and think to problems and solutions. In addition, it gives a key role to collaboration and cooperation that sometimes in schools are not sufficiently considered, limiting solely to individual results.

To the best of our knowledge, currently it does not exist a serious game integrating Virtual Learning Environments and Intelligent Pedagogical Agents, therefore this is an initial innovative point of our research. Moreover, so far the efforts in e-learning and serious games have been mainly focused on kids or to University students; the high school case is quite never considered, whereas there is an increasing interest in teaching STEM subjects in a different way in high schools. Finally, the majority of the e-learning systems are intended for distance teaching or used una tantum (like games), whereas the aim of the project is to change the classroom practice by using the developed game as a teaching tool (the same as an e-book). The majority of the existing serious games are not specifically designed, but are re-adaptations of existing games, or even worst, commercial games are used to teach STEM subjects. Thus, we argue that the outcome of the project will be a serious game prototype that integrates new
teaching trends and paradigms making use of the most advanced technologies. The prototype is currently under development, and the approach will be evaluated by experimentally using it in classes, especially for teaching STEM disciplines (physics in particular).

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