

## Cover page

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### Abstract

Electronic games have become part of children's culture. Children and adolescents are quite happy to spend many hours playing a game just for the fun of it. On the other hand educational syllabus may look quite dry to children and adolescents. In this paper, we describe VR-ENGAGE, a virtual reality game that has been constructed for teaching geography to students in a motivating way. Thus the captivating effects of electronic games may come into service for the purposes of education. The game is enriched with learner modeling mechanisms that ensure the individualization of the interaction. The game has been evaluated and the results were very encouraging.

# VR-ENGAGE: A Virtual Reality Educational Game that Incorporates Intelligence

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## Abstract

*Computer games have become part of children's culture. Children and adolescents are quite happy to spend many hours playing a game just for the fun of it. On the other hand educational syllabus may look quite dry to children and adolescents. In this paper, we describe VR-ENGAGE, a virtual reality game that has been constructed for teaching geography to students in a motivating way. Thus the captivating effects of electronic games may come into service to the purposes of education. The game is enriched with student modeling mechanisms that ensure the individualization of the interaction. The game has been evaluated and the results were very encouraging.*

## 1. Introduction

Children and adolescents are often fascinated by electronic games. Indeed, it has been widely acknowledged that electronic games are part of the popular culture of many children [1]. Children's fixation with these games initially alarmed parents and educators, but educational researchers soon questioned whether the motivation to play could be tapped and harnessed for educational purposes [2].

Hence a lot of researchers have recently highlighted the advantages of computer games relating to education. For example, Papert [3] points out that video games teach children that some forms of learning are fast-paced, immensely compelling and rewarding. Boyle [4] notes that games can produce engagement and delight in learning. In addition it has been argued [5] that games represent one way in which learners can be introduced into constructivist micro worlds, since users do not just study a particular domain but become part of the scenario.

However, if educators are to include electronic games as part of the curriculum then there is a need to do much more than invite the popular electronic games culture of

children inside the classroom walls [6]. Indeed, a major issue is how to design an educational system that is beneficial to students. Towards this end, there is a need for the integration of successful methods, ideas and approaches of educational software technology, such as the adaptivity abilities of Intelligent Tutoring Systems (ITSs).

ITSs have been quite good at providing dynamic aspects to the reasoning ability of educational applications. This is mainly due to their student modeling component that aims at gaining an understanding of how a student learns and what the student's misconceptions may be. Indeed, as Self [7] points out, ITSs are computer-based learning systems, which attempt to adapt to the needs of learners and are therefore the only such systems, which "care" about learners in that sense.

In this paper, we present a virtual reality educational game for geography. The game is called VR-ENGAGE which stands for Virtual Reality - Educational Negotiation Game on Geography. The environment of the game aims at increasing students' motivation and engagement. However, the game also incorporates intelligence. It has the main components of an ITS, namely the domain knowledge, the student modeling component and the tutoring component. In particular, the student modeling component models the student's knowledge and his/her ability to reason plausibly about domain knowledge acquired. In this way, while playing, students may practice both their factual knowledge on geography and their reasoning ability and thus they are led to "enjoyable" consolidation of knowledge.

The main body of this paper is organized as follows: In Section 2 the environment of the game is described and discussed. In Section 3 we describe the story of the game, which incorporates pedagogic features from educational software technology. In Section 4 we describe the student modeling component. In Section 5 we describe an evaluation that we conducted and finally in Section 6 we give the conclusions drawn from this research.

## 2. The Virtual Reality Environment of the Game

The environment of a game plays a very important role for its popularity. Griffiths [8] after conducting a questionnaire and interview study, found that the machine's "aura" typified by characteristics such as music, lights, colors and noise was perceived as one of the machine's most exciting features for a large part of the population questioned.

The environment of VR-ENGAGE is similar to that of the popular game called "DOOM" [9] which has many virtual theme worlds with castles and dragons that the player has to navigate through and achieve the goal of reaching the exit. VR-ENGAGE has also many virtual worlds where the student has to navigate through. There are mediaeval castles in foreign lands, castles under the water, corridors and passages through the fire, temples hiding secrets, dungeons and dragons. The main similarity of VR-ENGAGE with computer games like DOOM lies in their use of a 3D-engine. However, VR-ENGAGE unlike DOOM and other computer games of this kind is not violent at all and is connected to an educational application.

VR-ENGAGE communicates its messages to students through animated agents or through windows that display text. When a student is asked a question s/he may type the answer in a dialog box. The user interface employs two types of animated agent, the dragon which is the virtual enemy of the player and the virtual companion of the player. Both types of animated agent use synthesized voice as well as written messages. However, their voices are different so that the player may distinguish between them. The reason why the animated agents use voice is that there are studies that show that voice messages may be more effective than written ones in the way that students react to the educational applications (e.g. [10]). In addition, it was considered important for the "aura" of the game.

Players are also allowed to select whether they want background music or not. If they do, they are allowed to select the background music that they prefer from a menu. The reason why in VR-ENGAGE there is a high degree of choice for the status of the background music is that there is controversy as to what effects background sounds may have on performance. For example, a study conducted by Smith [11] has shown that background sounds may be stimulating but they may also have negative effects on performance. On the other hand, another experiment, which involved five computer games [12] has shown among other things that sound level had little influence on performance scores and errors. Therefore, in VR-ENGAGE, which is primarily aiming at educating players

and stimulating them to think, a player may turn off the sound if s/he feels that s/he is disrupted.

## 3. Rewards, Prizes, Threats, Negotiation and Virtual Companions

The story of VR-ENGAGE incorporates a lot of elements from adventure games. However, each of these elements is connected to ideas and pedagogic approaches from educational software technology.

The ultimate goal of a player is to navigate through a virtual world and find the book of wisdom, which is hidden. To achieve the ultimate goal, the player has to be able to go through all the passages of the virtual worlds that are guarded by dragons and to obtain a score of points, which is higher than a predefined threshold. The total score is the sum of the points that the player has obtained by answering questions.

In particular, while the player is navigating through the virtual world, s/he finds closed doors, which are guarded by dragons as illustrated in the example of Figure 1. A guard dragon poses a question to the player from the domain of geography. If players give a correct answer then they receive full points for this question and the dragon allows them to continue their way through the door, which leads them closer to the "book of wisdom".

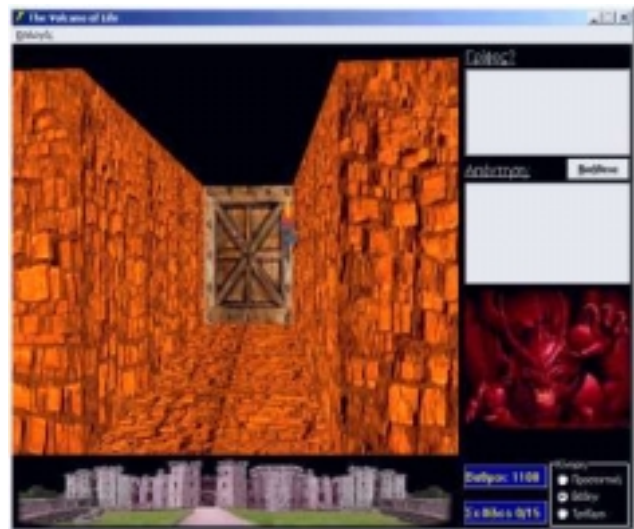


Figure 1. A door guarded by a dragon which asks a question

However, if a player is not certain about the correct answer, s/he is allowed to ask the dragon for a "negotiation". In this case the student is allowed to make a guess for which s/he has to provide a justification. The amount of points that the student is going to receive in the negotiation mode, depends on how close the student's answer is to the correct answer and/or how plausible the

reasoning that s/he has used is. If the answer that the student gives is absolutely correct then the dragon allows him/her to proceed through the door. However, if the answer is not completely correct then the system performs error diagnosis. The results of the diagnosis are communicated to the student through the virtual companion agent that appears to help the student.

In the negotiation mode, the student modeling component performs error diagnosis based on a cognitive theory of Human Plausible Reasoning [13]. At the end of this interaction, possible errors of the student and/or evidence of the student's lack of knowledge on a topic are recorded in the long term student model. For example, the student may have been asked the following question: "What is the capital town/city of the geographical compartment called Achaia (in Greece)?" While being in the negotiation mode, the student may give an answer such as: "My guess is that Rio is the capital of Achaia. I know that Rio belongs to Achaia; Rio is an important town in Achaia. Therefore, it is likely that Rio is the capital of Achaia." The student's guess may be correct or incorrect; in the case of the example, it is incorrect because Patras is the correct answer. However, the reasoning that s/he has used may reveal whether the student has a good knowledge of geography and whether s/he is able to use it plausibly.

In this sense the game provides an environment where there is opportunity for a negotiating teaching-learning dialogue between the ITS and the students. Collaborative discourse is an issue that has attracted a lot of research energy in the recent years (e.g. [14],[15]). The process of becoming an expert in a certain domain should no longer be solely viewed as the acquisition of a representation of correct knowledge; the knowledge to be acquired should flexibly manage open problems [16].

If a player does not know the answer at all or has given an incorrect answer without having asked for negotiation, then s/he does not receive any points and may only continue his/her way if s/he asks for help. In such cases the virtual companion appears and lets the student know what the correct answer is, so that the door may be opened. In addition the virtual companion suggests to the student to read a particular section of the lesson, which is mostly relevant to the question that s/he did not know how to answer correctly. The appropriate section is selected based on the error diagnosis performed by the student modeling process.

The existence of the virtual companion in the game has been considered quite important for the promotion of the student's sense of collaboration similarly with a lot of other recent educational systems. For example, Kay [17] notes that there is a growing acknowledgment of the importance of the learner's social context therefore systems are increasingly being designed for learners working in groups of real or simulated peers.

In terms of the game score, which represents the student's mark, the "negotiation" option may be better than an immediate incorrect answer of the student. This is so because the student may gain points for a plausible guess (although they do not gain full marks) whereas if s/he gives an immediate answer to the dragon, which is incorrect s/he does not receive any points at all. The idea behind this design decision is to encourage students to tell the truth about what they know and what they do not know and to practice their reasoning skills when they do not have an immediate answer.

#### **4. Student Modeling in VR-ENGAGE**

The student modeling component of VR-ENGAGE examines the correctness of the students' answers in terms of the students' factual knowledge and reasoning that they have used. Information about each student concerning his/her knowledge and reasoning ability, is recorded in his/her long term student model. The long term student model [18] keeps a history record of the student and is updated every time the student answers a question. The long term student model is used to adapt the presentation of lessons to the particular student's knowledge and possible weaknesses.

The student modeling capabilities needed for the negotiation mode of the game, are based on Human Plausible Reasoning theory, henceforth referred to as HPR. This theory formalizes the plausible inferences based on similarities, dissimilarities, generalisations and specialisations that people often use to make plausible guesses about matters that they know partially. Important inference patterns in the theory are the statement transforms. These inferences may lead to either correct or incorrect guesses; in any case these guesses are plausible.

HPR has been adapted and used previously in intelligent environments for novice users of UNIX [19] and for novice users of a Graphical User Interface [20]. Moreover, it has been applied in an ITS authoring tool [21]. The previous adaptations of HPR in a variety of domains, which were very different from one another and from the present one, shows that HPR could be very promising as an underlying reasoning mechanism in educational applications. Therefore, it has been adapted for the particular circumstances of an educational computer game that aims at teaching students both the domain of geography and the way to reason about facts plausibly.

In the context of the game, HPR has been used to add human-like reasoning abilities to the animated agents that interact with the students. In particular, when a student is asked a question from the domain of geography, HPR is used to perform error diagnosis in case of an error and to find out how close the erroneous answer has been to the

correct one. The outcome of the negotiation process is recorded to the long term student model and is used to adapt the presentation of the teaching material to the individual student. Moreover, in case a student asks for negotiation when s/he is expected to give an answer to a question in geography, the system employs the inference mechanism of HPR to evaluate the plausibility of the student's answer in terms of the model of human reasoning that HPR represents. In the negotiation mode, the student is asked to give explicitly the reasoning for the answer that s/he gives and is not certain about.

For example, the question: "What is the capital town/city of Achaia?" that was mentioned previously, corresponds to the statement: capital(Achaia)=Patras, where "capital" is a descriptor, "Achaia" is an argument and "Patras" is a referent. Based on HPR, the erroneous answer that the student has given in the example: capital(Achaia)=Rio corresponds to a similarity referent transform because the two towns belong to Achaia and they are similar in terms of the importance of their harbours. Therefore the student's answer is considered close to the correct one and the student receives some marks for his/her answer (although not full marks of course). However if the student gives a totally irrelevant answer then s/he does not receive any marks at all.

## 5. Evaluation

One important reason for the incorporation of an ITS into a virtual reality game was the objective of making educational software more engaging and motivating than other forms of software while retaining and even improving the underlying reasoning mechanisms. At a first glance, this might look as an obvious achievement of the game. However, there may be students who are not used to games and thus might not like them in classroom. On the other hand, the educational game may fall short of the expectations of frequent game players since they may have high demands for the game environment. Finally students may be distracted by the game and may not learn from the educational content of the application.

In view of the above, an evaluation of VR-ENGAGE has been conducted so that the design assets and deficiencies could be highlighted. The evaluation mainly consisted of a comparison between VR-ENGAGE and an ITS with a conventional user interface but with the same underlying reasoning mechanisms as VR-ENGAGE. This kind of evaluation was conducted as an experiment, which involved school children and took place in classrooms while human tutors were present but were not actively involved in the evaluation.

In particular, the experiment involved a class of 16 school children of 11-12 years old and two human teachers of this class that were present during the

experiment. The class were divided into two groups of 8 children, group A and group B. The division of children into two groups was based on the human teachers' selection of children in such a way that the two groups had the same distribution of students having good, average and bad grades in geography.

Group A was given VR-ENGAGE to work with for two hours. Group B was given an ITS which consisted of the underlying reasoning mechanisms of VR-ENGAGE but had a simple user interface with no game. Both groups were told by their human teachers that they had to complete a test using the software. In the environment of VR-ENGAGE this meant that they had to open all doors in a virtual world and reach the exit. In the environment of the ITS they had to answer a set of questions, which were displayed to them in plain text and context. The rules for the students' receiving their marks through the software were the same for both groups. In both applications, the mode of negotiation existed. However, in the ITS there was no adventurous context associated with it. Finally, both groups were supervised by two computer assistants who helped them with their interaction with the computer.

After the children had used the programs, the marks they had obtained and the errors they had made were collected in their user protocols since all their actions had been recorded. Then, the designers of VR-ENGAGE interviewed students.

On average, the students who had used VR-ENGAGE had spent more time with the system than the students who had interacted with the ITS. This was partly due to the fact that there was more to explore in the game therefore students needed more time to complete the game. However, most importantly, it was also partly to the fact that the players of VR-ENGAGE had spent more time reading the lessons that were shown to them than the other group of students. This showed that VR-ENGAGE was indeed more engaging.

After the interaction with either of the two systems, students were asked again to answer the same test questions where they had originally made a mistake. The players of VR-ENGAGE remembered the correct answers to a higher extent than the other group of students. This showed that VR-ENGAGE had achieved its aim of being at least as effective as an ITS in the learning outcomes and was in fact better than the ITS in this respect.

Finally, the interview showed that the players of VR-ENGAGE were fascinated by the idea of a game in the classroom and they were certainly happier than the other group of students. However, most of them also spontaneously commented on the game elements before they were even asked about them. In general, they pointed out that the game would be better as a game if it had more virtual objects, more background sounds and more adventure. This was due to the fact that most of them were familiar with commercial virtual reality games therefore

they compared VR-ENGAGE with them and had higher expectations in this aspect.

The fact that the students who had used VR-ENGAGE commented on aspects concerning the game itself showed a potential of this game to be used by children at their leisure time. This would mean that VR-ENGAGE could replace other computer games, which did not have any educational value, in the children's preferences for their entertainment. Indeed, this is an issue that is going to be addressed in future versions of VR-ENGAGE.

## 6. Conclusions

Educational applications may benefit from the technology of virtual reality games, which can increase the students' engagement and motivation. However, one major problem of this kind of educational application is the construction of the game itself and the connection of pedagogy and student adaptivity with the story of the game. The approach taken in VR-ENGAGE that we described in this paper offers a solution to this problem. VR-ENGAGE employs animated agents who take part in the story of the game by asking questions, and by providing adaptive advice and collaboration to the student. The tutoring adaptivity to the student's needs is provided by a domain-independent reasoning mechanism that performs error diagnosis and records the student's progress in the student model. The system has been evaluated and the results of the evaluation show that it has greater acceptability and effect on students than an educational application with a conventional user interface.

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