



Towards Educational Video Games with Enhanced Virtual Players

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Abstract. Virtual players, or so-called non-player characters (NPCs) play an important role in educational video games, as they help designers create a more engaging, realistic, and effective learning environment. Realistic and believable NPCs applied in appropriate ways are able to enhance both user experience and game learnability. The paper presents results from the development of an educational video maze game dedicated to the medieval history of the Bulgarian Kingdom and applying both simple and enhanced NPCs as assistants for the real player. While simple NPCs use a predefined tree-based dialog for communication with the real player and have non-adaptive emotions, the enhanced NPCs apply a smart conversational agent for answering player questions and possess an adaptive emotional behavior based on the emotional state of the real player recognized by neural networks. The preliminary results show that players report an improved game experience for the game version that has NPCs, especially for enhanced NPCs. The paper discusses unsolved issues in building realistic, believable, and effective NPCs and outlines directions for further studies.

Keywords: game · NPC · education

1 Introduction

Since their inception, serious (or so-called applied) video games have pursued the achievement of a goal by the players that is different from pure entertainment [1]. Although serious games are used in various fields such as vocational training, advertising, politics, defense, and others, their main focus remains learning and teaching. A number of scientific studies have proven that the use of such educational video games increases the engagement and motivation of learners [2, 3] and thereby leads to higher efficiency of the learning process and greater satisfaction among learners, which is reflected in improved learning outcomes and development of skills and competencies [4, 5].

Since the 1980s, educational video games have started using virtual players (so-called non-playable characters or NPCs) to better interact with players and create a more engaging gaming experience. Video games such as “Where in the World is Carmen Sandiego?”

[6] began to apply NPCs to help players solve puzzles related to geography. As technology has developed in the current century, NPCs have become increasingly complex and interactive. Simulation and strategy games such as “Civilization” and “SimCity” include NPCs that interact with players, providing them with additional information and new challenges to make the game more interesting [7]. In recent years, various educational games have been designed that integrate NPCs using artificial intelligence. Such advanced NPCs are able to adapt their behavior depending on the actions, behavior, and results of the real player. Examples of such games are “Minecraft: Education Edition” and “Kahoot!”, which use NPCs as virtual assistants, helping the player to master the didactic content in various academic disciplines [8].

The research problem of the present study consists in the creation and use of effective virtual players in educational video games of the type of three-dimensional maze, enriched with mini-games presenting didactic tasks of a diverse nature [9] and enhanced NPCs. The article presents a historical video game dedicated to the medieval history of Bulgaria (specifically, the royal dynasty of Assenevtsi from the 12th and 13th centuries). The game is formally described using XML, and the XML document includes a description of the connectivity of the maze, the interior of the halls in it, the educational boards and mini-games displayed in the halls, as well as characteristics of the virtual players used. The XML description was used to automatically generate a video maze in the Unity environment, after which an online version of the game was created and tested in a browser.

The paper is structured as follows: next section provides a background in the area of using NPC in educational games and their roles and purpose for enhancing player engagement, motivation, and learning effectiveness. Next, Sect. 3 outlines educational video mazes with virtual players (NPCs). It explains how NPCs are applied in the Assenevtsi maze game and how NPC behavior is adapted according to the emotional state and outcomes of the real player. The result section presents game experience found for simple and enhanced NPCs and discusses the challenges found in their development and application. Finally, the conclusion summarizes the findings of this research and outlines some directions for further studies.

2 Background

2.1 Educational Video Games Having Virtual Characters

Virtual characters are an important element in educational video games, as they help create a more engaging, realistic and effective learning environment for players [10]. They are an integral part of most modern video games, as they add depth, realism and opportunities for interaction. Examples of the application of NPCs in educational video games in recent decades can be summarized in several groups depending on the didactic area of the game:

- Medicine and healthcare: as virtual standardized patients used for medical training with realistic simulations to practice clinical skills [11], or for automated assessment [12]. “Squire’s Quest!” is an educational game using NPCs to improve healthy eating habits in children [13].

- Humanities: for history teaching to improve engagement, problem solving, and learning [14] and for assessing knowledge and skills [15]. In ethics education, NPCs have been used to generate narratives with adjustable moral choices [16], as well as to promote empathy and sympathy for different perspectives [17].
- Science: for mathematics teaching in the AutoTutor environment [18], in narrative-centered educational environments [14], and for science education [19].
- Business and Economics: for project management training [15, 20] and for business and economics to identify and address deviant student behavior [21] and for assessing knowledge and skills [22].
- Social Skills and Communication: for foreign language training [23] and for developing communication, negotiation, and leadership skills [24].
- Creativity and Arts: for creativity and design training [14, 15] and for music and performing arts training [23, 24].

2.2 NPCs Roles in Educational Video Games

NPCs can serve multiple roles with specific purposes in the game, such as providing necessary information and training, simulating realistic social interactions, presenting different perspectives and opinions, evoking emotional reactions in the player, provoking critical or unconventional thinking and decision-making, and assessing knowledge and skills. Depending on their purpose, the role of an NPC can be:

- A teaching assistant who provides information and feedback to the player [14, 16, 19, 23];
- Testing and assessing the knowledge and skills of the real player [11, 12, 16, 19, 25];
- A rival or adversary with whom the real player competes – e.g. through competitive gameplay with NPCs representing different historical civilizations in “Civilization VI” [26] or NPCs embodying historical figures in Assassin’s Creed: Discovery Tour [27];
- A partner with whom the player interacts to achieve a specific goal, for example to simulate realistic social interactions [21–24];
- A virtual character that helps to create a believable and engaging game environment [14, 16, 19] in order to improve user experience and engagement in different contexts – Riedl and Bulitko [28] suggest that the balance between believability and effectiveness depends on the context – in entertainment applications, believability may be more important, while in educational settings, effectiveness may take precedence.

In each of the roles outlined above, NPCs can be used in educational video games to improve engagement, motivation, and effectiveness of the game-based learning process. Creating believable and effective NPCs in virtual worlds remains an important topic that has significant consequences on the quality of interaction and user engagement.

3 An Educational Video Maze Game with Virtual Players

3.1 Educational Video Mazes

Educational video maze games combine interactive learning with problem-solving challenges. They motivate players to explore theoretical concepts while navigating through engaging mazes and challenges. This approach encourages players to practice their skills

and develop critical thinking. The players strengthen their understanding of various topics and improve their critical thinking skills while exploring the maze. This approach fosters subject-specific proficiency, making educational video maze games an effective tool for modern education.

Educational video mazes can be used successfully in various disciplines, from history and mathematics to science and language learning [29]. They connect theory and practice and transform passive learning into engaging. These games provide the possibility for student-centered education by integrating adaptive learning elements, such as intelligent NPCs, interactive storytelling, and AI-driven feedback.

Research and implementation of educational video maze games have demonstrated their effectiveness in adaptive learning, where players navigate through a structured environment while interacting with didactic mini-games, NPCs (non-player characters), and intelligent agents [30]. The Video Maze Generator [29], designed for the automatic generation of educational games, provides a framework for creating such games from non-IT people. The platform allows teachers to incorporate text-based challenges, visual storytelling, and AI-driven NPC interactions. The Video Maze Generator provides intuitive tools and templates, and it allows teachers to focus on creating challenging tasks and high-quality learning materials rather than worrying about technical details. In this way, more educational courses can incorporate maze video games, enriching the learning experience across various subjects.

3.2 Generation of Video Mazes

The Video Maze Generator is developed as a plugin in Unity 3D. As shown in Fig. 1, it uses the following three stages to create educational video games:

- **Game definition** – the maze generation begins with a connectivity editor, where the structure and pathways of the maze are defined. In this stage the game creators using the Maze Editor should define the game maze, difficulty levels, and learning objectives associated with each section of the maze. The Connectivity Editor enables the design of maze halls and the transitions between them. For each maze room the content creators and game designers specify the multimedia content (wall and floor textures, event-triggered audio, objects in the room, etc.), the learning contents and how it is presented, the mini-games available for the hall, and the conditions for transitions between rooms. This information is stored in XML and used to generate the maze;
- **Automatic game generation** – based on the information in the XML file, the system generates the game code to implement the interactive elements. This includes the code for the game maze, mini-games, non-player characters (NPCs), and intelligent agents;
- **Game export** – the maze game is built and exported by the generated source code from the previous stage. The result is a Unity 3D game, ready for deployment and player interaction.

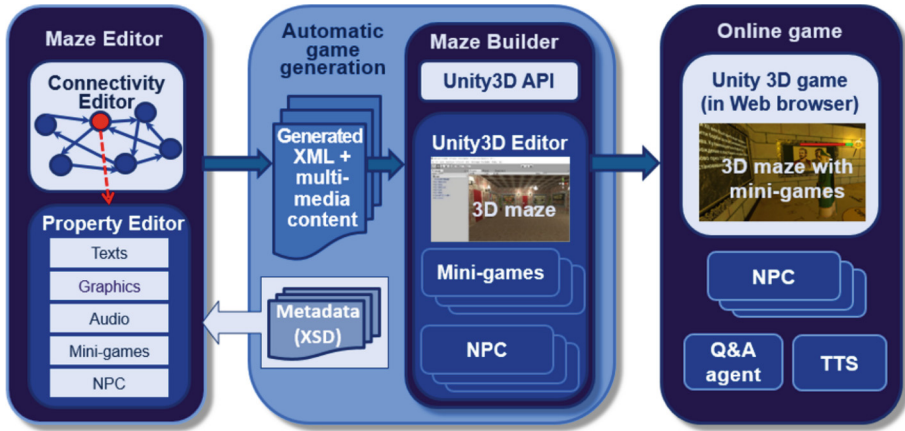


Fig. 1. Generation of video mazes with mini-games and NPCs

3.3 Assenevtsi Video Maze Game

The Assenevtsi game is an educational video maze that focuses on teaching Bulgarian history and culture through a dynamic, adaptive, and interactive learning experience. The game's design and features are tailored to provide a personalized and engaging way for players to explore and learn about the medieval historical aspects of Bulgaria.

The maze halls in the Assenevtsi game feature the following types of mini-games:

- Question and answer – players must answer questions to unlock a and access new rooms in the maze (Fig. 2a);
- Ball rolling – players roll balls to specific positions on a geographic map placed on the floor of a maze hall (Fig. 2b);
- Word soup – players find words hidden in a grid of letters (Fig. 2c);
- Arrange images – players have to arrange images on the floor in their time order or following other rules (Fig. 2d);
- Memory game – players match pairs of tiles with identical or related images and/or text (Fig. 2e);
- Quiz game with levels – players answer quiz questions to test their knowledge on specific historical and cultural topics (Fig. 2f).

The Assenevtsi game features a user-oriented adaptation process, meaning the difficulty level of educational tasks (mini-games) and the behavior of virtual players (i.e., NPCs) dynamically adjust based on the player's progress and engagement.

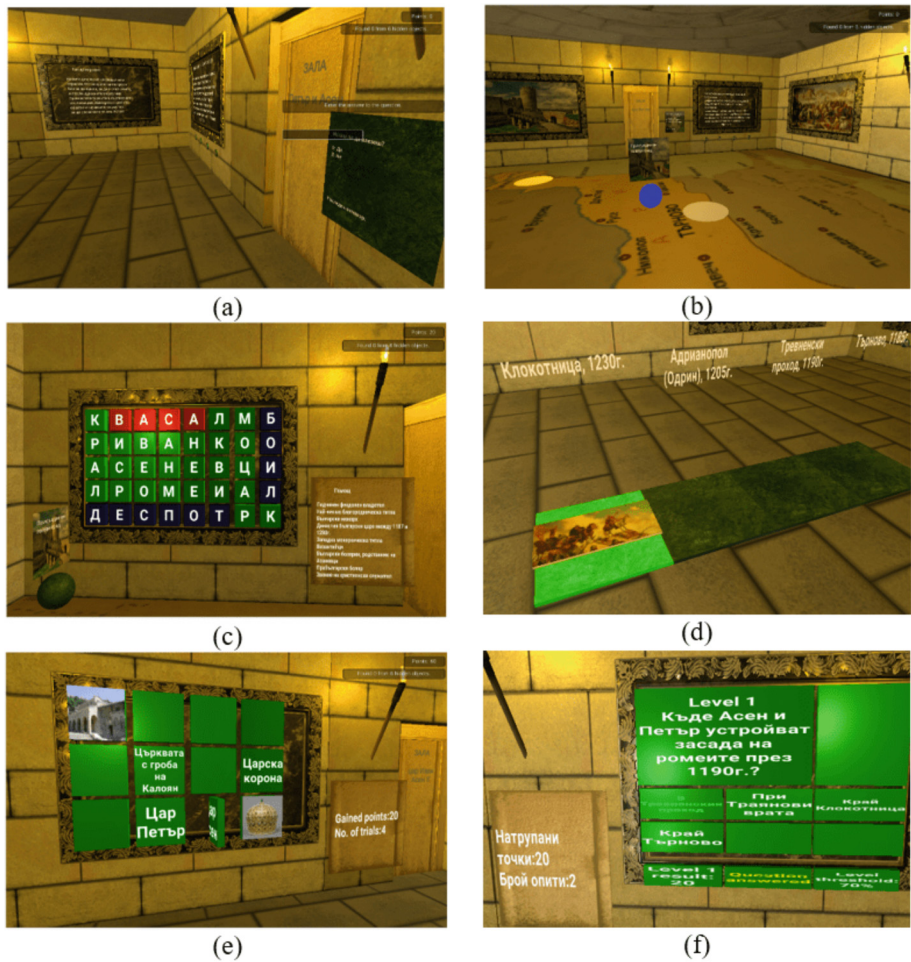


Fig. 2. Screenshots of some of the mini-games in the Assenevtsi game

3.4 Virtual Players in Assenevtsi

In the Assenevtsi game, both simple and intelligent virtual players (non-player characters or NPCs) are used. At any moment during the game, the player can choose or change the avatar of the virtual player if desired. Each of the four available avatars has its own animated behavior, controlled by scripts. The selected avatar appears in the game, moves around the maze, and visits only accessible halls (Fig. 3). The avatar can also display emotions, representing the virtual player's mood, which can be angry, sad, neutral, or happy (Fig. 4).

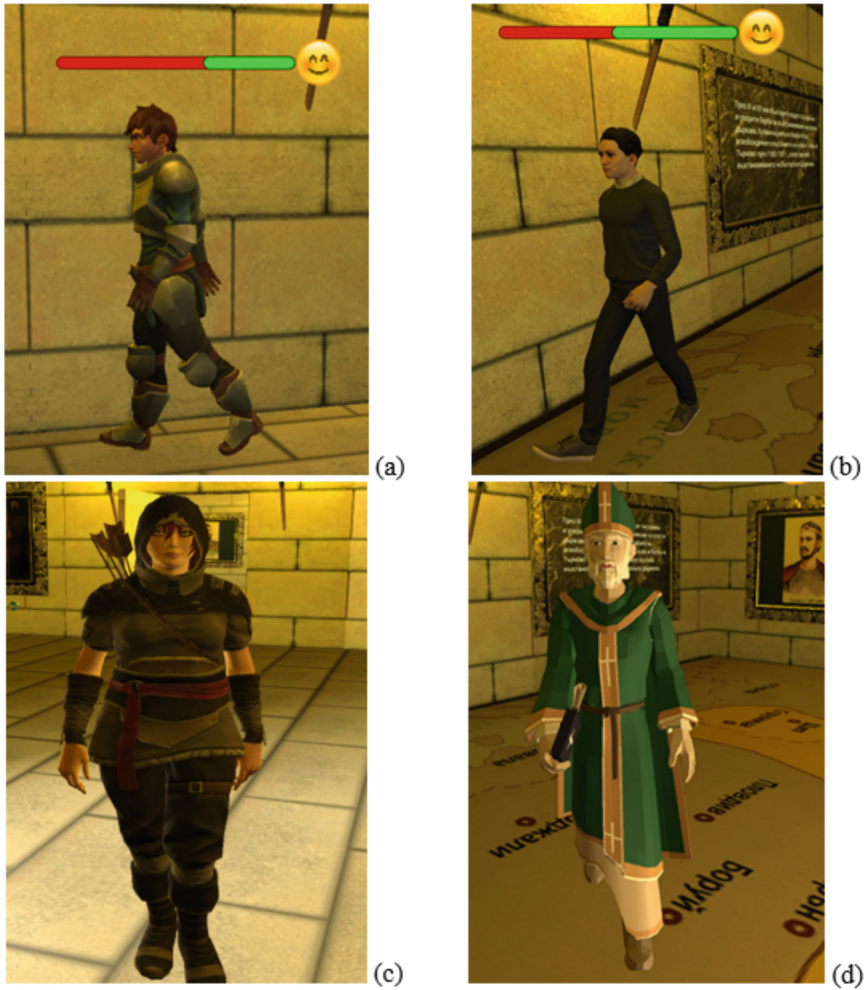


Fig. 3. Screenshots of implemented avatars (a-Boil, b-Vlad, c-Kossara, and d-Teofil)



Fig. 4. Emoticons states

The NPCs emotional state constantly changes based on the actions of the real player. The transition of states follows this order: Angry $\rightarrow$ Sad $\rightarrow$ Neutral $\rightarrow$ Happy. The same order applies in reverse: Happy $\rightarrow$ Neutral $\rightarrow$ Sad $\rightarrow$ Angry. The state icons (emoticons) represent these transitions as shown in Fig. 4.

The avatars in Fig. 3a and b illustrate the emotional state of the virtual player. A progress bar, colored green and red, indicates the transition toward a new emotional state. The red color represents a shift toward a worse emotional state, while green indicates an improvement. The transition from one state to another occurs when one of the two colors occupies the entire bar. In the case illustrated in the Fig. 3a, the red color takes up 70% of the bar, while the green takes up 30%. If we perform an action that the virtual player does not like, the red color will occupy more than 70% of the bar, and when it reaches 100% of the bar, the emotional state changes to a worse one. At the end of the bar, an emoticon represents the current mood of the virtual player—in the case shown in Fig. 3, the character is happy.

The virtual player can be summoned using the key combination Ctrl+v. Upon arrival, the avatar bows, allowing players to start a conversation with it. For simple virtual players, conversations follow a predefined static dialogue tree, where the player selects different options by clicking (Fig. 4). For intelligent, enhanced virtual players (NPCs), the player can ask free-form questions, which are sent over the Internet to an intelligent conversational agent. The received response is visualized in the game.

3.5 Virtual Players with Adaptive Behavior

The adaptability in Assenevtsi is represented through the dynamic change of difficulty in some of the educational tasks presented in the mini-games in the maze rooms. This change is managed depending on the emotional state of the real player, varying linearly within an interval defined by threshold values of:

- Player arousal – derived from measured values of individual electrodermal activity (EDA) and blood volume pulse (BVP) recorded by a useful model device.
- Player emotions – derived from facial expression analysis performed by a convolutional neural network.

To evaluate player emotions, the game utilizes artificial neural networks, one of the most effective and widely used techniques for emotion recognition [31]. Player emotional state (including arousal and six basic emotions) is applied in the control block for tailoring both the game difficulty (so called dynamic difficulty adjustment, or DDA) and the behavior of enhanced NPCs. DDA and NPC behavior are adapted by means of a finite automata applying as input parameters the emotional state of the player and his/her outcomes in the game [31]. Next, this adaptation is accessed by the player by receiving feedback in real-time using the adaptation control panel [32].

4 Results

Simple and enhanced NPCs were evaluated by practical gaming sessions with the Assenevtsi online game. 28 students aged from 19 to 23 years (13 males and 15 females) took part in the experiments playing the game with both types of NPCs – simple and enhanced. After the game session, players filled an online version of GEQ [33] for evaluating each component of game experience, namely flow, challenge, competence, positive and negative affect, immersion, and tension. Figure 5 presents values of the

seven components of game experience found for simple and enhanced NPCs. T-tests proved statistically significant differences in mean values between simple and enhanced NPCs for immersion ($p < 0.0001$), flow and negative affect ($p < 0.01$), and for challenge and tension ($p < 0.05$), respectively with intermediate up to small effect size (Cohen's d between 0.48 and 0.15) (Fig. 6).

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Fig. 5. Fixed tree-based dialog with a simple NPC

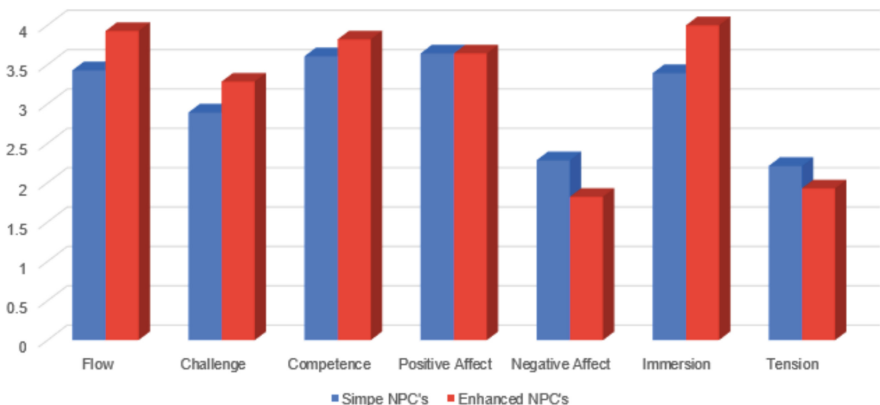


Fig. 6. Components of game experience found for simple and enhanced NPCs

Main challenges and problems found in the Assenevtsi game appeared related to the NPCs. The most important of them are as follows:

- Limited intelligence and realism of NPCs – in some cases NPCs demonstrate limited communication skills, decision-making, and realistic behavior. NPCs approach but

don't quite achieve human-like behavior. One solution for this is to incorporate in the educational games advanced machine learning and natural language processing techniques to improve NPC intelligence and natural human behaviors. Additionally, more sophisticated models can be developed to simulate human-like behavior, emotions, and interactions;

- Limited personalized experience for players – the reason for it is that NPCs often remain static and do not individually respond to the player's actions. This can be resolved by implementing adaptive systems that adjust NPC behavior based on the player's profile and actions. Additionally, the inclusion of branching scenarios and dynamic dialogues would provide more personalized and interactive experiences;
- Lack of integration of NPCs with educational content – often NPCs are not effectively tied to the learning objectives of the game. One solution can be to keep close collaboration between game developers and educational content experts to ensure the correct alignment between game mechanics and educational objectives. In addition, NPCs can be used more directly to deliver educational material, assess player knowledge, and provide timely feedback.

Taking into account these challenges and their possible solutions, it would be possible to be implemented more intelligent, realistic, and learning-effective NPCs in educational video games. Smart NPCs in immersive virtual environments will allow personalized learning processes with an enhanced student engagement and motivation, by providing tailored challenges and feedback, with adaptive difficulty ensuring optimal progression of each learner [25, 27]. By adjust the complexity of tasks based on student performance they can track individual student progress, offering valuable analytics for personalized instructions and data-driven insights.

5 Conclusions and Future Works

This study explores the role of educational video maze games in enhancing learning experiences through adaptive technologies, intelligent NPCs, and interactive storytelling. The proposed Video Maze Generator framework demonstrates its potential to simplify game creation for non-IT professionals while allowing for the integration of adaptive learning elements. The Assenevtsi game is a practical example showing how educational maze games can effectively incorporate enhanced NPCs, personalized learning, and emotional states to make the learning process engaging.

The main existing problems related to the use of NPCs include the need to implement NPCs that are more intelligent and realistic, more effectively personalize learning and game content to players, and seamlessly integrate educational content. Solving these problems will require the use of more advanced techniques from machine learning and human-computer interaction. Several directions for future work could be planned here:

- Enhancing NPC intelligence – implementing more advanced machine learning models and natural language processing to allow NPCs to conduct realistic dialogue and decision-making;
- Expanding emotional adaptation – improving the emotion recognition models to allow NPC reactions based on player behavior or physiological parameters;

- Developing more dynamic narratives – incorporating procedurally generated story-lines that adapt to player choices, increasing engagement;
- Optimizing game accessibility – by incorporating support for different learning styles, disabilities, and multilingual features;
- Conducting large-scale user studies - evaluating the effectiveness of adaptive educational maze games through empirical research involving diverse student populations and measuring their long-term impact on learning outcomes.

By addressing these aspects, educational video maze games can evolve into even more powerful tools for adaptive and personalized learning.

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