



Ready to Play - A Comparison of Four Educational Maze Games

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Abstract. The increasing use of game-based learning necessitates software platforms and technological tools to create serious video learning games. This article presents the APOGEE process for the automated creation of maze video learning games and describes the development methodology. This methodology has been applied to the design of four educational video maze games enriched with various mini-games. They are in different thematic areas – two considering Bulgarian history in the 12–13 and 18–19 centuries, one game presenting the national characteristics of the old Bulgarian carpet industry, and another game dedicated to the monumental cultural heritage preservation in the era of intensified climate changes. The paper briefly describes the four video games and also presents their creation process, with a discussion about the game design.

Keywords: Educational video games · Maze · Puzzle · Game-based learning

1 Introduction

Last decade, educational video games appeared to be a promising tool for achieving better learning engagement among digital natives, thanks to their interactivity and visual attractiveness. Much research outlines various benefits of the use of serious games, and especially video games, in educational settings [1, 2]. Pedagogical practice asserts that blending traditional and innovative approaches to teaching is the most efficient. Contemporary educational games can inspire students’ curiosity, provoke their interest and stimulate their motivation through competitive elements [3, 4]. Further, they can present learning content and didactic tasks appealingly and entertainingly. Also, they enable alternative and more involving ways of learning content presentation, thus causing the effect of “imperceptible learning”. Different video games have educational potential, as they can offer autonomous learning and learning by doing while exploring the game context [5]. Much research shows that educational games can be more efficient than traditional learning approaches. The advantages are related to the motivation and engagement of students and the resulting learning outcomes [1, 2, 6]. Enriched educational video maze games are specific maze games with several halls, traversal paths,

and various built-in mini-games. The game-based learning (GBL) approach is beneficial for both knowledge acquisition and the assessment of students' acquired knowledge [7]. Several studies explore application areas of serious games – education, healthcare, military, economics, social activities, etc. [1, 6].

Despite the many benefits of educational games, their wide usage is hampered by the lack of free games in various subject areas. In addition, most of the available software tools and platforms for designing and creating educational games require significant effort and solid knowledge and skills in information technology. Thus, this issue usually hinders teachers develop even simple computer games intended for a particular subject and learning goals. This issue can be solved using generators of different kinds of 3D video mazes with embedded learning tasks and learning content [8].

The applied approach's novelty consists of formal textual descriptions of educational maze games enriched with various mini-games and their automatic generation. This paper explains how the method of game generation is applied to creating four educational video maze games enriched with mini-puzzles. It is structured as follows: Sect. 2 introduces survey findings on teachers' views on educational maze games and describes the process and methodology for developing such games within the APOGEE project software platform. Next, descriptions of all mini-games integrated into maze video games are given. The paper briefly describes the designed four different thematic areas of video games and compares their characteristics.

2 Research Background

The authors conducted an online survey among school and university teachers ($N = 198$) to explore their views on educational maze games, preferred types of mini-games to be built-in, and usability of the APOGEE platform for game creation [9, 10]. The questionnaire applies a 5-point Likert scale. Before the survey, the respondents must watch a short video presenting the sample educational game generated by the APOGEE platform. Then they were asked to play the same maze game to become acquainted with the built-in types of mini-games. Here are presented some unpublished survey findings.

2.1 Teachers Need Educational Video Games

Teachers' opinions for the age group of learners for which the educational video mazes games are appropriate are presented in Fig. 1, applying a scale from 1 to 5.

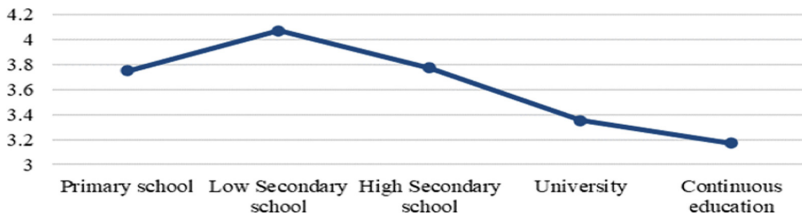


Fig. 1. Appropriateness of video maze games for training.

Based on their experience, the respondents consider these games most suitable for low secondary school students (ages 11–14 years), followed by primary and high secondary students. These findings correspond almost with the usual target group of educational games. Hence, such games are highly appropriate for GBL in schools and less applicable to other students. However, very few are available educational games focused on continuous education.

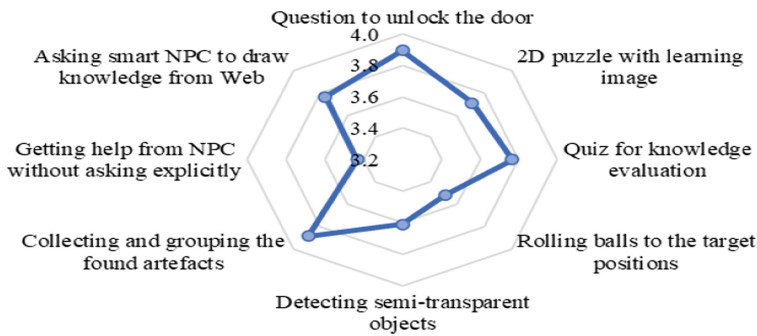


Fig. 2. The preferences of teachers to different type of mini games.

Respondents have to point out what types of mini-games they prefer mostly to be built-in in the educational maze games. Figure 2 reveals that they favour most questions for unlocking maze doors and collecting and grouping the found artefacts, followed by a quiz for knowledge evaluation, asking intelligent non-playable character (NPC) to draw knowledge from the Web, and a 2D puzzle with learning image. Thus, these mini-games are perceived as appropriate for pedagogical purposes, presenting didactic tasks engagingly. However, the range of preferences is relatively small (0.46), so teachers can use all types of puzzle games for content introducing and testing depending on particular learning goals and context.

The survey findings show a positive attitude of teachers toward GBL and their need for software platforms to create educational video games effortlessly (Fig. 3).

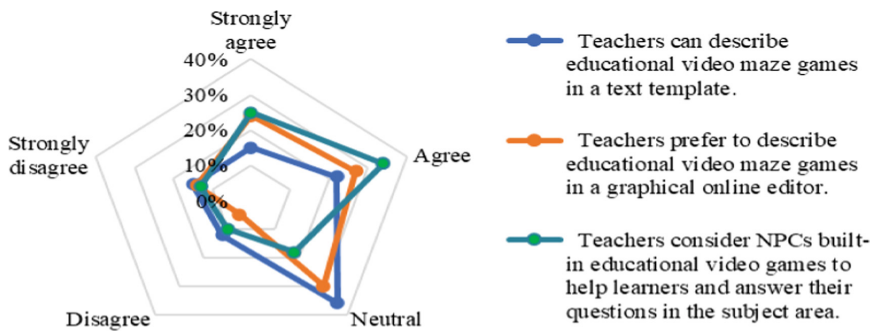


Fig. 3. Teachers' opinions about the process of creation of educational video maze games.

The respondents also find appropriate all the mini-games considered for building into the maze game. In general, they are optimistic regarding the functionalities offered by the APOGEE platform for automatized generation of educational video games. The expressed teachers' opinions give us the stimulus for enhancing the game construction platform. Thus, till now, we have created four prototypes of video games on different topics using the APOGEE platform. This paper presents these educational games.

2.2 The Process for Automatized Creation of Educational Maze Games

Unlike other existing approaches for the online generation of educational games, like quizzes [11], the APOGEE education software platform provides the opportunity to quickly and easily design, create and automatically generate educational video maze games [12]. It is done with the help of specially designed software instruments, which assist and support game designers in creating and evaluating the designed video games within the APOGEE platform [13]. Figure 4 illustrates the creation process of the APOGEE educational video maze game. In general, the process of creating an educational video maze game in the platform consists of 9 steps the designer goes through.

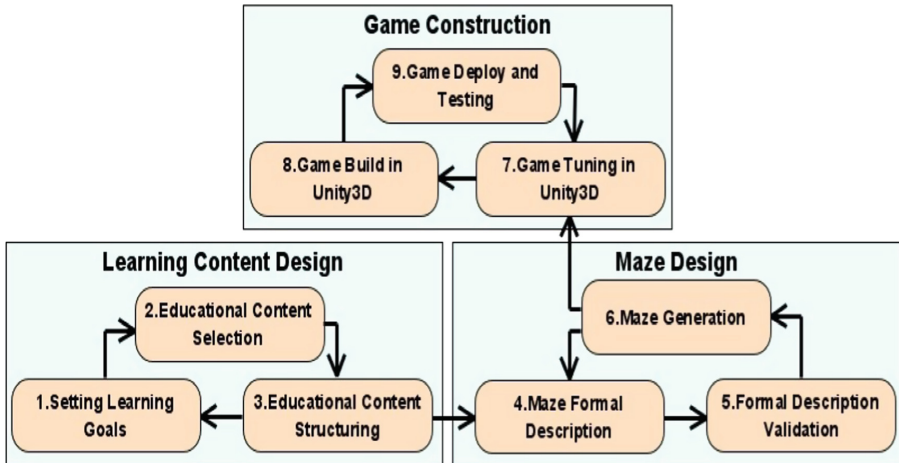


Fig. 4. APOGEE process of creation of educational video maze games.

The game designer can use these tools (assistive and analytics) to take advantage of them and facilitate their work. As a result, these instruments contribute to the creation process of educational video maze games that are specially designed to meet all available requirements, such as standard and conceptual requirements [15] related to the exposure environment, its aspects and virtual design [16, 17], as well as requirements as an educational purpose and goals, learning user groups, game and didactic content, user gaming, and learning experience and many more. As a result, a created educational game is available and ready to play by the users for whom it is intended.

2.3 The APOGEE Methodology for Creation of Educational Maze Games

The APOGEE Methodology for designing and developing educational video games aims to facilitate teachers and educational professionals to build 3D educational mazes enriched by 2D and 3D mini-games of various types [14] representing multiple puzzles and didactic tasks. The APOGEE explorative video game scenarios can be arranged in an imaginary world in several consecutive maze halls (similar to the popular escape room games). To achieve the mission goals, the player must pass through all maze halls, complete the mandatory and optional mini-games, and collect the maximum number of points (i.e., achieve the maximal result). The process of learning and playing should take a minimum time with maximum efficiency. To enter a new hall, the player must unlock the door by answering specific questions. The didactic content can be placed on the learning boards in the halls, in puzzle games, and hidden objects. After completing the maze, the player may opt between continuing the play, repeating the game, or finishing the play.

The game development platform APOGEE [18] is based on a formal XML description of the enriched maze created in an incremental and iterative process. It presents the structure and interior of the maze, together with the learning multimedia content and presentation and settings of the didactic mini-games. The XML description, together with game graphics and audio resources, are supplied to a custom plugin installed in the Unity 3D editor [19] and responsible for the generation of 3D mazes. Thus, the design of APOGEE 3D educational video mazes follows these consecutive steps:

1. Setting learning objectives of the game and explorative maze scenario;
2. Defining learning content, formatting text, images, audio, and multimedia files;
3. Design of the audiovisual layout of the maze halls;
4. Choice of suitable didactic mini-games, built-in content, and allocating them in the maze;
5. Building an XML document describing the maze and its mini-games;
6. Generation of the maze in the Unity 3D editor;
7. Fine-tuning the maze game in the Unity 3D editor (if needed);
8. Building executable versions of the game and distributing them among the players;
9. Testing and validation of the game prototypes with target users.

The following versions of the generated maze game can add personalization of the content and adaptation of task difficulty [20, 21]. Several online versions of the maze game can be built and deployed on the APOGEE Web server.

3 Description of Four Educational Maze Games

The APOGEE platform educational maze games generated contain a set of mini-games in their halls. These mini-games present the learning tasks students need to solve to reach the next room and gain the maximum score. The knowledge necessary for performing the tasks can be found on the information panel placed on the hall walls. Here are presented the mini-games used in the four maze games:

- In the “Open Sesame!” game, the players try to answer a question to unlock the door to the next hall. They type the chosen answer or its number in a textbox.

- The players fill in a Quiz with several questions to acquire game points for the final score or reach a trigger score for unlocking a door.
- To play the “I see you” mini-game, the user must detect and click on trans-lucent objects thematically related to the learning matter in the maze halls.
- Within the “Find me!” game, in the maze halls, the user must uncover many objects hidden in or behind larger ones.
- In the “Memory” puzzle, players search for matching couples of cards placed in a grid with the blank side up.
- Within the “Word soup” puzzle game, a set of letters is arranged in a gridiron. The player looks for words that are relevant to the subject matter and are arranged vertically, horizontally, or diagonally.
- The player must organize a set of objects by providing features in the “Divide & Conquer” mini-game. The game objects used are thematically related to the educational domain and can be gained in other puzzles in the maze halls.
- The user must arrange a two-dimensional instructional image by moving their elements to the proper locations in the “2D puzzle” game.
- The FPS (First Person Shooter) mini-game requires the player to shoot at unanimated moving objects, for example, flying balloons.
- In the “Roll a Ball” mini-game, the players move several balls (labelled with text or images) by rolling them to the matching places or objects on the floor.

In addition to the described mini-games, some maze games presented below include NPC [22], who interacts with the player. The NPC gives information that can be necessary for completing the didactic tasks or curious facts related to the learning domain in the hall. He searches for educational content in a database or reliable websites.

Next, this section presents four didactic maze games created by the APOGEE platform with their thematic domains, target groups of players, and screenshots (Fig. 5).

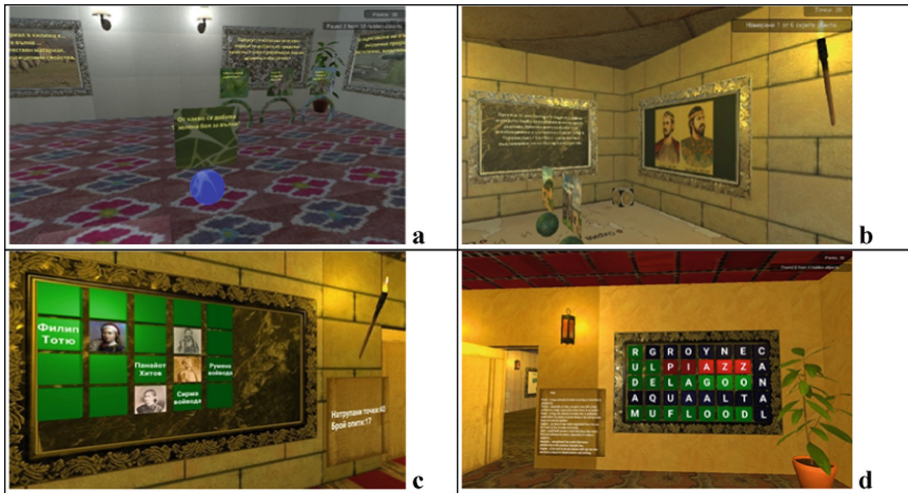


Fig. 5. Screenshots of the fourth educational maze games: a) “The carpet industry in Bulgaria”, b) “The Dynasty of Asenetsi”, c) “The Legacy of Valchan Voyvoda”, d) “Let Us Save Venice”.

The first described didactic maze game is the “Carpet Industry in Bulgaria” [23], dedicated to cultural-historical heritage preservation and Bulgarian ethnography. It presents the handicraft of carpets after the XVII century in three Bulgarian towns. The six halls are thematically related as follows: Introduction Hall, the rooms West and North West from the first loop are dedicated to carpet weaving in Chiprovtsi, the joint North room present the carpet industry in Sliven, and the last two halls (East and North East) – Kotel’s carpets. Five halls include hidden objects and “Roll a Ball” mini-games. The exception is the central hall which is a part of both loops. A recorded video with sample gameplay is available at <https://youtu.be/ZLH4F6gq9Gs>.

The second “The Dynasty of Asenevtsi” [19] game’s thematic topic is Bulgarian medieval history from the 12th and 13th centuries. This game comprises information from the following three time periods: the uprising of Peter and Assen, the ruling of King Kaloyan, and King Ivan Assen II. The maze includes four halls, the first one for introducing the game, and each of the following three is dedicated to one of the periods mentioned above. The player must go through the first three halls to reach the last one, solve the tasks, and answer the questions for unlocking the doors. The game ends after all the objects hidden in the halls are found. This game targets the audience of fifth- and sixth-grade students, corresponding from 12 to 14 years old adolescents. A sample video is available at <https://youtu.be/ml9NwiZOrB0>.

The next game is “The Legacy of Valchan Voyvoda” [24], which is dedicated to the life and work of the legendary Bulgarian Valchan voivode. The player passes through the maze halls by answering questions for unlocking the doors, solving various didactic tasks, and searching for hidden objects. This educational maze game contains seven halls with the following topics: 1. Introductory; 2. Age; 3. Who is Valchan Voyvoda; 4. Lifework; 5. The Legacy; 6. Valchan Voyvoda today; 7. Treasure. The game ends after the player visits every maze hall and finds all the hidden objects. A sample video is available at: <https://youtu.be/QI5bplmxxZo>.

The fourth presented game, “Let Us Save Venice” [12], intends to educate viewers on the effects of climate change, especially as it relates to sea-level rise and cultural heritage destruction in areas like Venice [25]. To finish the game, the players must solve all required puzzles, pass through the maze, and detect the translucent objects. They can go to the next hall by answering a topical question correctly and earning the highest possible score. On the hall’s walls are boards with information concerning the didactic mini-games and questions. The maze contains five interconnected halls: Introduction, Context, The Problem, The Solution, and The Future. The game is targeted at students from a variety of specialties in different universities. The thematic area is significant and influences all national and age groups, and “Let Us Save Venice” is therefore suited for life-long learning and information activities. A recorded video with a sample game-play is available at <https://youtu.be/YiBI2K9hC88>.

4 Discussion

All four educational video games outlined in the previous section are of maze type enriched by various 2D and 3D mini-games. The maze games have been constructed using the APOGEE platform to automate the creation of smart games for learning.

Table 1 presents a comparison of their main characteristics. All the games are generated by using the APOGEE software platform from XML formal descriptions that differ in language, number of maze halls, number of learning boards, and included mini-games (such as different types of mini-games and number of game instances embedded into maze rooms), audio resources and images incorporated in maze halls, and inclusion of NPC's and automatic TTS (Text-To-Speech) translation. The four games also differ in the time needed for generating the maze in Unity 3D Editor (based on the XML formal description and archives with images and audio) and the time necessary for the game to be built as a desktop application or a browser WebGL game.

Table 1. Characteristics of the developed video games of type enriched maze.

Game Feature	Carpet Industry in Bulgaria	The Dynasty of Asenetsi	The Legacy of Valchan Voyvoda	Let Us Save Venice
Language	Bulgarian	Bulgarian	Bulgarian	English
Number of halls	6	5	8	5
Number of learning boards	48	34	54	38
Mini-games (types/instances)	3 / 9	6 / 13	5 / 12	5 / 8
Audio resources	6	5	8	5
Images	98	118	147	82
XML (lines / kB)	801 / 32	1026 / 107	1203 / 154	771 / 102
NPCs included	No	Yes	No	No
TTS	No	Yes	No	No
Maze generation time	2 sec	5 sec	5 sec	4 sec
Time for game build	3.5 min	6.2 / 14.6 min	7.9 / 18.3 min	12.3 min
Distribution	Desktop	Desktop/Online	Desktop/Online	Online

With increasing the number of game resources (text, images, and audio files) and the size of the XML document, both these times increase. However, the time needed for maze generation remains relatively shorter than the time for a game build (desktop or online). Nevertheless, the time for maze generation and the one for the game build are much shorter than the time for collecting and structuring learning content, which may be extended up to several weeks or months. Provided that game designers have the didactic content ready (e.g., structured in a lesson or a textbook), they have to create an XML formal description, either by using the APOGEE graphic editor for maze creation and further validation and generation of the XML file, or manually through an XML template for describing enriched maze games. The XML document should be validated using an XML Schema definition of enriched maze games. Next, this XML document is given to the APOGEE Maze Builder, which generates the maze game in the Unity 3D editor. The generated maze game can be immediately built employing the Unity Builder interface; however, some minor modifications need to be done, such as relocations of game objects, changes in illumination, etc. The game can be distributed through the players by sending

them the executable files (for desktop games) or the Internet (for any game). Next, the games can be played without restrictions or in a controlled mode. The last is applied for game validation and includes pre-game quizzes (e.g., for acquiring demographic characteristics of the players, their previous gaming experience and knowledge in the domain, learning style [26] and playing style [27], etc.), game sessions with tracking of player performance and outcomes, and post-game quizzes for assessing game experience [28] together with playability and learnability [29]. All four games have been validated successfully, having excellent results in-game experience, playability, and learnability [12, 14, 23, 24].

5 Conclusion and Future Work

The paper presented four educational video games constructed using the APOGEE game platform. The first game (“Carpet industry in Bulgaria”) is focused on the manufacture and industrial development of the carpet industry in Bulgaria; the second one (“Let Us Save Venice”) is dedicated to climate resilience of built cultural heritage and the last two games are about Bulgarian history namely about the legacy of the legendary Valchan Voyvoda (who has lived in 18–19 century AD) and about the dynasty of Asenevtsi during the Second Bulgarian Kingdom (12–13 century AD). This comparison is limited only to some game characteristics (Table 1), but the authors plan to evaluate the four games through practical experiments with target users.

The game platform APOGEE has been validated as a promising instrument and methodology for designing and developing learning games adapted for multiple educational scenarios. The maze provides an easy-to-understand structure of the multimedia learning content, including different challenges presented as mini-games and puzzles. The future steps cover wider dissemination among target audiences, attracting teachers and experts, and even learners and students to design and deploy various educational games. Further efforts will be made to improve the mini-games’ personalization and adaptation possibilities, learning analytics, and smart services for delivering more enjoyable, efficient, and learner-oriented educational experiences.

Acknowledgements. The research is partially supported by the APOGEE project, funded by the Bulgarian National Science Fund, No. DN12/7/2017.

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